The pedagogical use of technology-mediated feedback in a higher education piano studio: an exploratory action case study

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Statement of originality

I confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Existing research evidence suggests that the application of technology can be beneficial in instrumental and vocal learning. However, it is not clear how technology-based feedback might be used in advanced level piano lessons to enhance learning and teaching. An exploratory action case study approach was undertaken in Brazil to investigate systematically the pedagogical use of technology-mediated feedback in a piano studio. Technology-based data were provided by the researcher as a facilitator for three pairs of higher education teachers and students across two lessons each in order to evaluate possible/actual changes and improvement in participant students' performance. Three data sets were captured: video recorded piano lessons, technology-generated data regarding keyboard and pedalling activity, and audio-recorded interviews with teacher and student participants. Two piano lessons for each case study were conducted, and semi-structured interviews were also undertaken with each participant separately after each piano lesson. Qualitative analysis involved a multi-methods approach which focused on reporting and comparing the process and outcomes for each pair of participants. Findings suggest that technology-enhanced feedback provides potentially useful additional feedback, both in real-time and post-hoc. The usefulness of such additional feedback was shown to relate to the individual and to the shared priorities of the particular teacher and student pair. Whilst user biases revealed preferences for either visual or auditory cues, it was shown that shared experience which draws on enhanced sensory modalities can decrease discrepancies between teacher and student perspectives of learning priorities, and increase awareness of appropriate learning foci.

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1 Introduction

1.1 Background of the researcher

My personal interest in using technology to support piano practice began when I recorded my own performances in rehearsals at home, or in live performances using a cassette recorder. Since then, I have witnessed various changes in technology, such as for instance from cassettes and minidiscs to hard-disk based recording and from video-cassette recording to digital camera recording. Audio and video recording of my solo and chamber music performances during my career as a pianist served three purposes: first, to make a career portfolio with my presentations and repertoire; second, to evaluate my own performances; and third, to record my musical development.

Apart from performance experience, my main activity in the music field has been as a piano teacher giving one-to-one weekly lessons to 8-13 year-old students, starting in 1996. One year after, I started to give small group piano lessons to 5-12 year-old students at The British School in Rio de Janeiro, Brazil, as an extra-curricular piano teacher, which is equivalent to the role of Music Service teachers in mainstream schools in the United Kingdom (UK). In 2003, I took the position of keyboard teacher at the Baden Powell Music School, also in Rio de Janeiro. At this state music school, I learned to teach students of different levels of expertise, age, and diverse socio-economic backgrounds.

In parallel with my teaching, I maintained my career as a solo and chamber music pianist by performing from the Western classical repertoire alongside the work of living composers, particularly Brazilian composers. After concluding my MMus dissertation on the musical and pedagogical analysis of eleven preludes by the Brazilian composer Edmundo Villani-Côrtes, I started to record and release my first CD album.

I became interested in researching the use of technology-mediated feedback in higher education (HE) piano learning and teaching when I was recording and producing my first CD album between late 2007 and early 2008, in Rio de Janeiro. During the editing stage of the CD production, I observed that the recording graphs gave me visual information about my performance in a waveform output. In addition, I observed that the sound engineer was able to indicate which sections of different recording tracks could or could not be joined together whilst editing, purely by looking at the waveforms of the recorded performance on the computer screen. That intrigued me.

This doctoral study thus arose from my curiosity to investigate the application of technology in a piano learning and teaching setting. My own previous experiences fostered an interest in understanding the nature of feedback and in investigating the prospective application and benefits or otherwise of additional visual-auditory feedback generated by technology in one-to-one HE piano learning and teaching.

1.2 The context of this thesis

The starting point for this thesis was my particular interest in investigating the pedagogical use of additional feedback generated by technology to foster improvement of learning and performance in HE one-to-one piano lessons. There is a rich literature focusing on interaction between teacher and student in conventional one-to-one piano tuition in general (Kostka, 1984; Siebenaler, 1997; Speer, 1994), on HE instrumental or vocal learning and teaching in looking at a particular instrument (Bryant, 2004; Burwell, 2010), and on perspectives of teachers and students in conventional HE instrumental learning and teaching (Gaunt, 2007, 2009, 2011). However, teachers and their students do not seem to share the same perspective on what needs to be learned and taught as they reported different learning priorities in the customary HE piano studio (Hamond, 2013b, 2013d). This might be related to the master-apprenticeship model of transfer learning which is usually used in this context (Hallam, 1998; Jørgensen, 2000).

It is suggested that a transformative pedagogical approach occurs when technology is used in instrumental and singing learning and teaching (Creech & Gaunt, 2012). Several researchers have shared the same interest and have reported the perspectives of students on using various types of technology in HE when watching video recordings of their own performances (Daniel, 2001), when using instructional media in piano group lessons (Benson, 1998), when analysing graphical representations of recorded data by well-known pianists and themselves (Riley, 2005; Tomita & Barber, 2008), and when using audio recording and playing back of their own performances (Zhukov, 2010). In addition, additional visual feedback generated by technology in real-time is reported to have enhanced HE singing learning and teaching in the UK, even if pedagogical approaches differed according to individual teachers (Welch, Howard, Himonides, & Brereton, 2005). However, the actual application of additional feedback generated by technology alongside teachers and students in instrumental lessons, particularly in HE piano studios, has been under-researched.

1.3 Rationale

The concept of *feedback* is central to this thesis. Feedback is a crucial aspect in enhancing learning. Wiener (1961) was the first author to use the concept of feedback, but in the field of cybernetics (see Chapter 2 for more detail). In educational settings, feedback involves information about student performance or understanding; it can be delivered by another individual such as the teacher or peer, by the individual themselves, and/or by an external source such as technology (Hattie & Timperley, 2007). Feedback is an essential aspect in motor control and learning (Magill, 1989; Schmidt & Lee, 2011), in classroom educational settings (Hattie & Timperley, 2007), and in music education, particularly in instrumental and vocal learning and teaching (Bryant, 2004; Burwell, 2010; Gaunt, 2007, 2009, 2011; Kostka, 1984; Siebenaler, 1997; Speer, 1994). Feedback is one of the behaviours which were observed in instrumental and vocal learning and teaching. Feedback is usually provided by the teacher through general (positive or negative) and specific feedback to the student, known as interpersonal feedback.

Feedback can be provided by an external source such as technology. The use of technology in learning seems to augment feedback through additional visual and/or auditory information. In the field of motor control and learning, learners can enhance learning when watching their own recorded performances, or graphic representation of performances while being assisted by their coaches (Magill, 1989; Schmidt & Lee, 2011). In the field of music education, technology can enhance learning (Himonides, 2012) such as in the HE music studio (King, 2008) or in the music classroom (Savage, 2007).

There is also evidence that the application of technology can enhance learning, since students can become more conscious of their own performances through self-assessment and the intrapersonal feedback system (Carey & Grant, 2015b; Daniel, 2001; Zhukov, 2010). Feedback in conventional piano learning and playing involves interpersonal feedback between the teacher and their student (Bryant, 2004; Burwell, 2010), and intrapersonal feedback through student visual, auditory and proprioceptive feedback systems (Banton, 1995; Bishop & Goebl, 2015; Finney & Palmer, 2003). In this thesis, it is argued that additional visual-auditory feedback generated by technology can enhance student learning and performance in the one-to-one HE piano studio.

1.4 Identifying an appropriate research paradigm

The research paradigm for this thesis adopted a constructivist paradigm where I, as the researcher, assume 'a relativist ontology (there are multiple realities), a subjectivist epistemology (knower and respondent [co-create] understandings), and a naturalistic (in the natural world) set of methodological procedures' (Denzin & Lincoln, 2005, p. 24).

Ontological, epistemological and methodological positions differentiate constructivism from the other paradigms, namely, positivism, post-positivism, critical inquiry, and participatory. According to Guba and Lincoln (1994, pp. 111-112), when adopting one paradigm these three 'positions have important consequences for the practical conduct of inquiry, as well as for the interpretation of findings and policy choices'. In constructivism ontology, relativism involves 'multiple, apprehendable, and sometimes conflicting social realities that are the products of human intellects, but that may change as their constructors become more informed and sophisticated' (Guba & Lincoln, 1994, p.111). Constructivism epistemology is based on the subjectivist assumption which 'sees knowledge as created in interaction among investigator and respondents' (Guba & Lincoln, 1994, p.111). Constructivism methodology is based on hermeneutic/dialectic and 'aimed at the reconstruction of previously held constructions' (Guba & Lincoln, 1994, p.112).

This study adopted an exploratory action case-study methodology in the specific context of HE piano learning and teaching, and qualitative research methods of data collection, analysis, and interpreting findings. A constructivist paradigm was used in this study rather than other paradigms since their ontological, epistemological and methodological positions were not suitable to this study. First, this study did not use experimental methodology, and verification of hypothesis, as commonly adopted in positivism and post-positivism paradigms. Second, this study did not focus on social, political, ethnic, or gender values required in critical inquiry paradigm or on political participation from participatory paradigm (Lincoln & Guba, 2000).

A constructivist paradigm was used in this study in order 'to explain the social world we need to understand it, to make sense of it, and hence we need to understand the meanings that construct and are constructed by interactive human behaviour' (Usher, 1996, p. 18). In addition, the constructivist paradigm seemed appropriate to the study since it is closely related to the ways that I understand the real world (Maxwell, 2005).

This thesis is an essentially qualitative social research study with quantitative aspects in which the stance of a constructivist paradigm is adopted in order to make sense of the phenomenon, which is the application of technology in HE piano learning and teaching:

> …a goodly portion of social phenomena consists of the meaning-making activities of group and individuals around those phenomena. The meaning-making activities themselves are of central interest to social constructionists/ constructivists, simply because it is meaning-making/ sense-making/ attributional activities that shape action (or inaction) (Lincoln & Guba, 2000, p. 167).

In addition, the methodology adopted in this thesis is an action case study approach which explores the application of technology-mediated feedback in the HE piano studio (see Chapter 5 for details). In the field of instrumental and vocal learning and teaching, most research studies have adopted a case study approach in their conventional setting by using observations (Benson & Fung, 2005; Bryant, 2004; Burwell, 2010; Siebenaler, 1997; Speer, 1994), and/or interviews (Bryant, 2004; Burwell, 2010; Gaunt, 2007, 2009, 2011). However, those researchers who have investigated the use of technology, particularly the application of real-time visual feedback (RTVF), adopted a more experimental approach in order to investigate specific aspects in vocal, or percussion learning and teaching (Brandmeyer, 2006; Sadakata, Hoppe, Brandmeyer, Timmers, & Desain, 2008; Welch et al., 2005). Within these studies, Welch et al. (2005) perhaps was the only one who conducted the experiment by applying RTVF generated by technology alongside the musical activities by teachers and their respective students for particular voice and musical performance parameters.

1.5 Research aims and research questions

The main purpose of this literature-based and action case study research is to investigate the nature of feedback and types of feedback which are available in piano learning and teaching when technology-mediated feedback, particularly visual feedback, is applied in HE settings. The second purpose is to examine how technology-mediated feedback might be applied by teacher and student pairs in a piano studio. The third purpose is to investigate whether and to what extent technology-mediated feedback might be useful in order to enhance HE student learning and performance.

A literature review discusses the nature of feedback in instrumental and vocal learning and teaching, including the types of internal feedback available to the student, the forms of teacher feedback in piano learning, and the attempts in recent studies to use technology in instrumental and vocal learning and teaching to enhance learning, such as through additional visual feedback.

Based on this field of interest, three research questions underpin the research:

1. What is the nature of feedback in higher education piano learning and teaching when technology-mediated feedback is applied?

2. How is technology-mediated feedback applied in higher education piano learning and teaching?

3. Does the application of technology-mediated feedback enhance higher education piano learning and teaching, and improve student performance in piano lessons?

1.6 Thesis structure

The thesis structure has been organized into twelve chapters. The first four chapters encompass the introduction and literature review. Chapter 1 introduces the background of the researcher, the context of this thesis, rationale of this study, appropriate research paradigm, research aims, and research questions. Chapter 2 describes the origins of the term feedback, feedback in the human body, especially in motor control and learning, augmented feedback, feedback and feed forward in classroom learning, individual differences, and variability of practice and feedback in learning.

Chapter 3 reviews the literature relating to intrapersonal feedback in terms of sensory feedback, for instance auditory, visual, and proprioceptive feedback in music, particularly in piano playing, and learning. Additional aspects in terms of brain activity in piano playing and learning, conscious-awareness, sense of self, self-regulation, and metacognition are also reviewed. A model of intrapersonal feedback in piano playing is also proposed so to describe the important types of intrapersonal feedback involved in piano playing and learning.

Chapter 4 reviews studies on interpersonal feedback between student and teacher, and between individuals and an external source, in terms of technology in instrumental and vocal learning and teaching. This chapter critically examines several studies of one-to-one instrumental and vocal learning and teaching in the Western classical music context. An overview of interpersonal feedback in HE level and other-than-HE contexts is addressed for one-to-one piano, small group piano, and individual other-than-piano learning and teaching. Musical performance parameters, including MIDI parameters related to piano learning and playing are also reviewed. An overview of interpersonal feedback between individuals and technology is also explored for technology and music education in general, and technology in piano and other-than-piano contexts. In addition, this chapter also briefly addresses RTVF in instrumental and vocal studies, and in piano-related studies. Tables present the meta-categories of verbal and non-verbal behaviours including feedback and the related musical performance parameters that are commonly explored in instrumental and vocal learning and teaching, with or without technology.

Chapter 5 sets out the methodology adopted in this study. An overall summary of the theoretical framework of additional feedback generated by technology in an HE piano studio is presented in the beginning of this chapter. Details of pilot case studies conducted for this thesis, the implications for the main study, and the final research design adopted are presented. An overview of the three methods for data collection, namely from video, technology, and interview is provided, alongside details of participants selection and materials used in this study. Chapter 5 also includes a discussion of the ethical codes which were adopted for data collection and analysis, and in reporting the findings. Approaches to multi-method data analyses are also reported which focus on in-depth qualitative data analysis (QDA) for video, musical instrument digital interface (MIDI), and interview data analyses.

Chapters 6 to 10 report the findings of the multi-methods analyses. Chapter 6 reports the findings of the video QDA for the behaviours of participants, and the verbal and non-verbal feedback derived from the cross-tabulation of the behaviours and musical performance parameters. Chapter 7 reports the findings of video QDA for the types of technology-mediated feedback used in the piano studio for each case study and across case studies. Chapter 8 reports the findings of video QDA for auditory feedback per case study according to the microstructure analyses of musical behaviour. Chapter 9 reports the findings on the MIDI QDA for additional visual feedback according to the musical performance parameters worked in lessons per case study. Chapter 10 reports the findings of the interview QDA for teacher and student perspectives on technology-mediated feedback use in piano studio. Chapter 10 also discusses teacher and student views on changes in learning and teaching, and on their experiences within this study.

Chapter 11 summarizes and discusses the findings. The multi-methods QDA findings are mapped onto the key issues raised in the literature review. Findings from the observation data, technology-generated data, and interview data are compared and discussed alongside findings from recent studies (Benson, 1998; Brandmeyer, 2006; Carey & Grant, 2015a; Creech & Gaunt, 2012; Daniel, 2001; King, 2008; Riley, 2005; Sadakata et al., 2008; Savage, 2007; Tomita & Barber, 2008; Welch, 1983, 1985b; Welch et al., 2005; Zhukov, 2010). The nature of feedback when technology-mediated feedback is used in the HE piano studio is discussed for various types of feedback, conscious-awareness of intended versus actual performance outcomes, associative learning, perspectives on changes in learning and teaching, and the prospective match of learning styles and teaching styles.

Finally, Chapter 12 offers the conclusion of this study by answering the three research questions. Models for the nature of feedback, pedagogical approach, and effective application of technology-mediated in HE piano studios to enhance student learning and performance are discussed. Implications for practice and policy, limitations of this study, and further research are also reported in this final chapter.

2 Literature review: concept of feedback

2.1 Introduction

Chapter 2, the first of three sections of the literature review, focuses on the various meanings and uses of the term ‘feedback’. In particular, an overview of ‘feedback’ in cybernetics and its relation to ‘learning’ is presented. Feedback in the human body is addressed in four of its forms, namely, inhibited feedback, feedback control, positive feedback, and negative feedback. Feedback in motor control and learning is reviewed through research studies on the form of inherent, intrinsic or sensory feedback through vision, audition, touch, smell, taste, and proprioception, and on the form of extrinsic or augmented feedback as provided by external sources such as teachers, coaches, and technology. Other types of augmented feedback such as Knowledge of Results (KR), Knowledge of Performance (KP), and video feedback, biofeedback, kinematic and kinetic feedback are also reported. An overview of feedback, feed forward, and assessment in HE settings is offered. The individual differences of learners in the feedback process are also recounted in this section. Forms of extrinsic feedback in music learning are reviewed through studies using variability of practice and KR. In Chapter 3, a detailed review of intrapersonal feedback in piano learning and playing is discussed while in Chapter 4 detailed reviews of interpersonal feedback in instrumental and vocal learning are reported.

2.2 Introduction to the term ‘feedback’

Feedback is a crucial topic in learning and teaching. The impact of feedback in several contexts has been reported in various studies: in classrooms (Hattie & Timperley, 2007; Hounsell et al., 2003), in motor control and learning (Magill, 1989; Schmidt & Lee, 2011), in the conventional piano studio (Kostka, 1984; Siebenaler, 1997; Speer, 1994), in HE instrumental learning (Bryant, 2004; Burwell, 2010), in music education using information and communications technology (ICT) (Himonides, 2012), and in vocal learning and teaching using technology-based feedback (Welch, 1983, 1985a, 1985b; Welch et al., 2005).

The term ‘feedback’ was first reported in the cybernetics field by Wiener (1961) to describe information about a variable which can be controlled (Schwartz & Andrasik, 2003). Wiener (1961, p. 6, original emphasis) ‘came to the conclusion that an extremely important factor in voluntary activity is what control engineers term *feedback*’. Cybernetic literature also indicates that feedback is relevant ‘to biology and to neurophysiology and psychology in particular’ (Annett, 1969, p. 18) and makes learning possible (Schwartz & Andrasik, 2003; Annett, 1969; Wiener, 1961), including musical learning (Welch, 1983, 1985a, 1985b). Wiener explains how feedback forms a loop for learning:

> …when we desire a motion to follow a given pattern, the difference between this pattern and the actually performed motion is used as a new input to cause the part regulated to move in such a way as to bring its motion closer to that given by the pattern (Wiener, 1961, p. 6).

There are two types of theoretical loop systems which control voluntary movements: *open-loop systems* and *closed-loop systems*. In general terms, the concept of feedback arose to explain closed loop systems.

An open-loop system is defined as a ‘control system with pre-programmed instructions [that] does not use feedback information and error-detection processes’ (Schmidt & Lee, 2011, p. 497). An example of an open-loop system is the unchangeable way that traffic lights work despite the occurrence of a car accident or a traffic jam (Schmidt & Lee, 2011). Another example of an open-loop system is the functioning of an alarm clock which will start to ring whether a person is still asleep or already awake. In other words, an open-loop system does not depend on feedback to work.

In contrast, a closed-loop system is conceptualized as a ‘control system employing feedback, a reference of correctness, a computation of error, and subsequent correction in order to maintain a desired state’ (Schmidt & Lee, 2011, p. 493). An example of a closed-loop system is a heating and cooling system, which starts or stops working according to the temperature outside the system. Thus, a closed-loop system relies on feedback from the environment, the outside temperature, and 'feedback is necessary for the mechanism to carry out the desired action' (Annett, 1969, p. 110).

Human motor control is considered to be a closed-loop system because movements rely on sensory information to interact with the environment. Sensory information 'tells us about the state of the environment, about the state of our own body, or about the state of our body with respect to the environment' (Schmidt & Lee, 2011, p. 135). When senses give information to the rest of the body, they are giving feedback to the body.

Open and closed-loop systems control voluntary movement. However, they differ in two main respects. First, 'a closed-loop control system involves feedback while an open-loop system does not' (Magill, 1989, p. 109). Second, in the open-loop system feedback 'is not used to control the ongoing movement', while in the closed-loop system 'feedback is used to help control the ongoing movement as well as to help plan the next response using this same movement' (Magill, 1989, p. 109). In other words, in the open-loop system 'the movement plan is complete', while in the closed-loop system 'the execution of the movement is dependent on feedback information provided from the sensory system' (Magill, 1989, p. 110).

2.3 Feedback in the human body

Following the development of the concept of feedback as outlined above, the occurrence of feedback processes and mechanisms can be found in biology where it is reported as a response which regulates a biological process. Types of biological feedback include: *feedback inhibition* (Gerhart & Pardee, 1962; Voet & Voet, 1995), *feedback control* (Magill, 1989; Schmidt & Lee, 2011), *negative feedback* (Campbell & Reece, 2009), and *positive feedback* (Annett, 1969; Campbell & Reece, 2009; Schmidt

& Lee, 2011). Each of these types of feedback processes and mechanisms is discussed below.

Feedback inhibition in the human body is exemplified by enzymological mechanisms where 'the concentration of a biosynthetic pathway product controls the activity of an enzyme near the beginning of a biosynthetic pathway' (Voet & Voet, 1995, p. 339). Thus, feedback inhibition can also be called end-product inhibition since the quantity of the final product of the biological process regulates the process itself by stopping it when the amount of the final product increases (Gerhart & Pardee, 1962; Voet & Voet, 1995).

Likewise, feedback inhibition in learning implies that the amount of feedback needed is reduced in line with the perceived progress of the student, for instance a reduction in feedback occurs in parallel with student progress. Examples of feedback inhibition in music learning might include decreased teacher feedback when student performance is deemed successful, and to prevent performance anxiety when a student is performing from memory.

Feedback control appears in some areas of human behaviour such as psychomotor learning (Magill, 1989; Schmidt & Lee, 2011), social psychology (Fiske, Gilbert, Lindzey, & Jongsma, 2010), and speech as a motor control mechanism (MacNeilage, 1970). In social psychology, for example, feedback control is related to the study of attitudes, social cognition, emotion, and expressive behaviour and to the examination of when and how people control their behaviour, when and how their behaviour occurs automatically and to what extent people are aware of their judgements, emotions and actions (Fiske et al., 2010). Feedback control occurs in musical learning because singing or playing an instrument involves psychomotor learning and monitoring of behaviour moment-by-moment.

Negative feedback is a mechanism which can be found in the human body for homeostatic regulation which controls body temperature, blood pH and blood glucose.

Homeostasis allows the body to ‘maintain a relatively constant internal environment even when the external environment changes significantly’ (Campbell & Reece, 2009, p. 861). Negative feedback in the human body occurs when a response diminishes a stimulus. For example, after vigorous exercise such as running, the body produces heat which increases its temperature. This response of increased temperature will be released to the homeostatic mechanism and the negative feedback will work in order to maintain a fairly constant body temperature. Thus, the body starts to sweat, this cools down the body and decreases the body temperature (Campbell & Reece, 2009). Negative feedback can be also found in endocrine systems when a decrease in the level of one substance circulating in the bloodstream promotes an increase in the secretion of other substance (Campbell & Reece, 2009).

Negative feedback in learning might be related to comments from teachers, or peers in relation to the performance or assessment outcomes of a student. Negative feedback in musical learning can be also associated with negative emotions such as anxiety, which can interfere with student motivation and self-confidence when playing or performing a musical piece. Negative emotions may arise from the way in which information is given to a student by a teacher in order to correct a perceived mistake in performance, such as through the use of a negative expression or comment.

Positive feedback in the human body occurs when a response of a mechanism amplifies the stimulus, for example, the substance oxytocin is released to the circulatory system of women in childbirth to intensify contractions (Campbell & Reece, 2009; Marieb & Hoehn, 2007). In learning, positive feedback can be related to encouraging a particular kind of behaviour. In the same way, positive feedback in music learning would support a positive shaping of musical behaviour towards a desired performance goal. Feedback in motor control and learning will be discussed next.

2.4 Feedback in motor control and learning

Feedback in motor control and learning has been reported by authors over a long time span (Gibson, 1968; Magill, 1989; Schmidt & Lee, 2011). According to Schmidt and Lee (2011, p. 4), 'it is often difficult to isolate a movement from its environment'. Thus, human movement is always likely to be related to the environment where the movement is produced. Humans perceive the environment and the way movement happens through their senses and through their receptors of sensory information (Gibson, 1968).

Sherrington (cited in Schmidt & Lee, 2011, p. 136) classified receptors of sensory information available during movement into three groups: *interoceptors*, *proprioceptors* and *exteroceptors*. The term interoceptors 'tell us about the state of our internal organs […], and have questionable relevance for motor behavior'. Interoceptors are also associated with 'the nerve endings in the visceral organs' (Gibson, 1968, p. 33). Proprioceptors refer to 'events in one's own body' or 'information about our own movements' (Schmidt & Lee, 2011, p. 136) and are related to 'the end organs in muscles, joints, and the inner ear' (Gibson, 1968, p. 33). Exteroceptors refer 'to events outside one's body' or 'information about the movement of objects in the environment' (Schmidt & Lee, 2011, p. 136) and are connected with 'the eyes, ears, nose, mouth, and skin' (Gibson, 1968, p. 33). Gibson (1968, p. 33) also summarized categories of exteroceptors, proprioceptors and interoceptors as devised by Sherrington (1906) into three types of correlated sensation categories as follows: '(a) sensations of external origin, (b) sensations of movement, and (c) vague sensations of the internal organs'.

Sensory information is that which is obtained through physical senses: vision, audition, touch, smell, taste, and *proprioception*. The proprioception sense encompasses information about the movement of the body and 'provides the basis for moving where our limbs are in space and is comprised of both static (joint/limb position sense) and dynamic (kinaesthetic movement sense) components' (Goble, Lewis, Hurvitz, &

Brown, 2005, p. 156). Additionally, 'in the production of coordinated movement, proprioceptive feedback has been found to be critical' in several movement actions, such as in controlling 'movement trajectories' and in 'providing internal models of limb representation used in acquisition and adaptation of skilled movement' (Goble et al., 2005, p.156).

Proprioception also encompasses the *vestibular apparatus and system* which influence physical motion by creating a 'subjective sense of self-motion and orientation thereby playing a vital role in the stabilization of gaze, control of balance and posture' (Cullen, 2012, p. 185). Vestibular feedback is multi-modally integrated with other-than-vestibular feedback types that are provided by the senses of vision, audition, and proprioception in order 'to ensure accurate motor control' (Cullen, 2012, p. 185). Apart from proprioception, vision and audition senses have also been reported in motor learning and control.

Vision is both *extereoceptive* and proprioceptive because it provides information from both the environment and the individual own movements, respectively (Gibson, 1968). Bridgeman (1996) provided an overview of the 'terms for the two branches of the visual system'; first: focal, experiential, cognitive, explicit, object or overt; and second: ambient, action, motor, sensorimotor, implicit, spatial, covert (Bridgeman, 1996, p. 192). Thus, focal vision is related to the type of vision required for reading a book or a music score, while ambient vision is linked to peripheral vision, which refers to vision for movements in an environment, such as the movements of other musicians in a chamber group performance.

Audition also provides extereoceptive and proprioceptive information for motor control. According to Schmidt and Lee (2011, p. 153) 'most of the movements we make in the environment produce sounds' and 'the nature of these sounds, then, provides us with a great deal of information about our actions'. In the same way that cyclists orient themselves in the dark through the sounds of objects and from their own movements, instrument players can monitor their musical performances from the sounds that they hear when playing their instruments and can modify or orient the way they play by playing softer or louder. In diving competitions, judges use sounds produced by the movement of divers when they enter the water in order to evaluate the level of expertise. Similarly, in a music context, sounds produced by instrumentalists and singers through their movement when performing, indicate levels of expertise in musical performance. For example, the sounds produced by pianists through their movements when playing the piano and through keyboard and pedalling activities are a major indicator of performance. Schmidt and Lee (2011) stated that 'auditory information is processed faster than visual information, but vision seems to provide more useful information than audition'. Thus, information provided through vision and audition can be called visual and auditory feedback respectively and plays an important role in learning and performing either in sports or in music, which can be perceived by the individual through their own internal system.

There are two types of feedback in motor control and learning which differ in one main feature. Hence, information depends on its source. Authors from the fields of motor control and learning address feedback in different ways by using distinct terms relating to each type of feedback source. Feedback which is produced by the person has been called *inherent feedback* or *intrinsic feedback* (Schmidt & Lee, 2011), or *sensory feedback* (Magill, 1989). Feedback produced by someone or something external to the person has been entitled *extrinsic feedback* (Schmidt & Lee, 2011) or *augmented feedback* (Magill, 1989) including *Knowledge of Results (KR)* and *Knowledge of Performance (KP).*

Inherent, intrinsic or sensory feedback may be conceptualized as the information that one person receives from their own movements and own senses. Hence, it has been seen as 'useful feedback about a response provided by the visual, auditory, tactile and proprioceptive systems' (Magill, 1989, p. 317). Extrinsic feedback or augmented feedback, which also includes KR and KP, comes from outside the person and is information which can be given by 'a teacher, coach, videotape, computer or any external source capable of providing information about an individual's performance'

(Magill, 1989, p. 317). Thus, when inherent feedback is insufficient to make the person perceive and understand information, it has been proposed that augmented feedback or KR is needed. In other words, augmented feedback can provide information which seems to support intrinsic, inherent or sensory feedback (Schmidt & Lee, 2011).

Table 2.1 describes each of the dimensions of augmented feedback in motor control and learning reported by Schmidt and Lee (2011, p. 394) when performing a movement which can be used in combination with another: (1) concurrent (concomitant) or terminal; (2) immediate or delayed; (3) verbal or non-verbal; (4) accumulated or distinct; (5) KR or KP. Although the two latter concepts seem to be similar, they are reported as being quite different. Whereas KR refers to the 'outcome of the movement in terms of the environmental goal', KP refers to the learner movement patterns (Schmidt & Lee, 2011, p. 395) or 'to information about the actual performance characteristics that produced or caused the outcome' (Magill, 1989, p. 318). Magill (1989) and Schmidt and Lee (2011) seem to have different perspectives in relation to how they designate KR and KP. Schmidt and Lee (2011) differentiate KR from KP whilst Magill (1989) incorporates KP and KR as:

> …information provided to an individual after the completion of a response that is related to either the outcome of the response or the performance characteristics that produced that outcome (Magill, 1989, p. 318).

For example, in sport, when one player did not see the ball coming closer to them, KR can be given by an instructor as "You missed the ball" to show that the environmental goal was not achieved (Schmidt & Lee, 2011, p.395). In contrast, when the instructor says "Your elbow was bent", they are giving KP to the player because the movement is the focus of the correction (Schmidt & Lee, 2011, p.395). However, in some cases KR and KP are difficult to distinguish from each other, mainly when the movement itself is the goal. In addition, KR 'can be highly specific or it can be very general' (Schmidt & Lee, 2011, p. 395).

Table 2.1 Ten dimensions of extrinsic or augmented feedback (adapted from Schmidt and Lee 2011)

Type of feedback	Characteristics of feedback
Concurrent	Presented during the movement
Terminal	Presented after the movement
Immediate	Presented immediately after the relevant action
Delayed	Delayed in time after the relevant action
Verbal	Presented in a form that is spoken or capable of being spoken
Non-verbal	Presented in a form that is not capable of being spoken
Accumulated	Feedback that represents accumulation of past performance
Distinct	Feedback that represents each performance separately
Knowledge of Results (KR)	Verbalized (or verbalizable) postmovement information about the outcome of the movement in the environment
Knowledge of Performance (KP)	Verbalized (or verbalizable) postmovement information about the nature of the movement pattern

An equivalent example in instrumental learning and teaching would be that KR can be given by a teacher as "you're still—old habits die hard—and you're bashing the down beats as well. So, the impact of the um accent is lost a bit", whilst KP can be given by a teacher when saying "[f]eel that your diaphragm is pushing lower rather than […]" (Burwell, 2010, p. 167). In both cases, KR and KP provide a type of augmented feedback with the aim of correcting or improving the inherent or intrinsic feedback related to the environmental goal and the movement itself, respectively. In the performance of music, both KR and KP are needed because the physical gesture or the body or hand movement, and the sound outcomes are intimately connected.

Another concept which has been increasingly used is *feed forward*. In some cases, '[feed forward] information can be thought of as a variant of feedback' (Schmidt & Lee, 2011, p. 173). Although feed forward seems to be related to feedback, in motor control and learning it has the characteristic of providing information which is given in advance in order to prevent errors, and 'serves an important role in error detection and correction, often occurring in anticipation of the error' (Schmidt & Lee, 2011, p. 175). In learning, feed forward seems to be a variant of feedback in the way that is information provided by the teacher which can be used by the student in a future performance or task either to prevent the same mistake recurring, or to improve future performances (see Section 2.7 for more detail).

In piano learning, one example of feed forward information in piano playing is shown when the teacher anticipates or perceives errors in student performance when watching the body or hand movements of the student, or by listening to their current performance. At such times, the teacher can give information to the student about their performance, which can be applied to prevent mistakes or improve future performance. Thus, feed forward information can have the function of correction before an errant hand or wrist movement, or even prevent an unintended interpretation in performance; this can make the learning quicker as the information on the current performance can also be applicable to future performance. Although feedback or feed forward are usually provided by teachers or coaches, augmented feedback can also be delivered by external sources such as technology and can provide information to enhance learning and performance. Other forms of augmented feedback are discussed below.

2.5 Augmented feedback

For Schmidt and Lee (2011) there are four powerful modes of giving augmented feedback, namely, *video feedback*, *biofeedback*, *kinematic feedback*, and *kinetic feedback*. Video feedback consists of using videotaped performances, or graphic representations of performances (Magill, 1989). Videotaping a performance might be more informative for beginners than for intermediate students or leaners, and might be most effective if used ‘for periods of at least five weeks’ (Magill, 1989, p. 341). At that time of writing, using computer graph representations of performances was reported as becoming ‘more common, especially at high levels of skill performance’ (Magill, 1989, p. 344). Finally, augmented feedback aims to augment or increase the sensory feedback and it is given ‘while the person is performing’ (Magill, 1989, p. 347). However, for any such methods ‘meaningful information must be presented’ and ‘the teacher still plays an important role in helping students’ (Magill, 1989, p. 342).

Although video feedback ‘will contain a record of the entire performance’ (Schmidt & Lee, 2011, p. 401), it is questioned whether the use of video feedback is an effective way to detect errors as it encourages students to correct errors by themselves. There is evidence that watching video recordings of performance without instructor feedback is ineffective for motor control and learning because it may provide too much information, which can confuse learners (Schmidt & Lee, 2011). Thus, several studies (Kernodle & Carlton, 1992; Wallace & Hagler, 1979) indicate that video replays, when combined with the instructions of teachers or coaches in order to depict the specific details for performance goals, might be more beneficial for the student or learner and, subsequently more effective for learning (Schmidt & Lee, 2011). Similarly, in the field of music learning, the use of video feedback through video recordings of student performances can assist students to understand and self-assess their own performances in self-study even though they feel uncomfortable in watching their own video recorded performances (Daniel, 2001).

According to Magill (2014), the effectiveness of using videotape replays and graphic representations of performances on kinematic and kinetic parameters depends on two main factors. The first factor is the '*skill level of the learner rather than the type of activity*' where the application of technology is particularly useful for beginners alongside instructors, and advanced learners working independently on their own (Magill, 2014, p. 359, original emphases). The second is that the technology '*[transmits] certain types of performance-related information more effectively than other types*', and facilitates learning on 'those performance features that performers can readily observe and determine how to correct on the basis of what they see on the video replay' (Magill, 2014, p. 360, original emphases).

Biofeedback can also be a form of augmented feedback when 'a particular biological process (e.g. blood pressure) is measured electronically and used as feedback, then subjects can learn to voluntarily control these (normally unconscious) processes' (Schmidt & Lee, 2011, p. 404). Biofeedback supplies 'individuals with increased information about what is going on inside their bodies, including their brains' (Schwartz & Andrasik, 2003, p. 10). Biofeedback can also be called 'external psychophysiological feedback, physiological feedback, and sometimes augmented feedback' (Schwartz & Andrasik, 2003, p. 10) or neurofeedback (Gruzelier & Egner, 2004).

In the field of music performance, one of the uses of biofeedback in musicians was reported in an overview by Gruzelier and Egner (2004). Biofeedback or neurofeedback studies have ascertained that one purpose of making musical performers, such as violin and clarinet players, aware of unnecessary tension is that it allows them to understand how it causes pain in their arms, face, or other parts of the body whilst they are performing. Other studies showed that players became more aware of muscular movements after receiving biofeedback or neurofeedback (see Gruzelier & Egner, 2004, for an overview).

Other types of reported augmented feedback are kinematic and kinetic feedback. Although they seem to be similar, these two types of feedback are also different. Kinematic feedback is another form of providing KP which 'involves various measures derived from movement such as position, time, velocity, and patterns of coordination' (Schmidt & Lee, 2011, p. 402). In contrast, when coaches or teachers give information about movement patterning, for example, "[you] bent your elbow that time", they are really providing a loosely measured form of kinematic information, a form of KP (Schmidt & Lee, 2011, p. 402).

In instrumental learning, if the piano teacher says, "[c]an you try and get the breath support going before the, the note speaks […], but just make sure that you're taking the strain there before you release the air" (Burwell, 2010, Appendix C, p.7), they are giving kinematic information because they are telling the student about a movement or physical gesture that they perceive needs to be changed or corrected. It can be argued, then, that a 'key feature of kinematic feedback is that it informs the subjects about some aspect of the movement pattern that is otherwise not perceivable' (Schmidt & Lee, 2011, p. 402).

In contrast, kinetic feedback is related to 'the *forces* that produce the kinematic variables' (Schmidt & Lee, 2011, p. 405, original emphasis). Kinetic feedback considers the use of 'muscular forces and durations over which they act are fundamental outputs of the central structures thought to organize movements' as well as useful information for motor control and learning (Schmidt & Lee, 2011, p. 405). For example, in the music field, when the teacher gives information about how much harder the student must strike the key for a *fortissimo* chord, the teacher will be providing kinetic feedback because it relates to the force used to produce the movement and, in this case, it is designed to produce a louder sound. The student, then, might use more force in their movement in order to make the chord sound louder in comparison to their previous attempt.

Likewise, in music learning, augmented feedback in the forms of video recordings (Daniel, 2001), and audio recordings (Zhukov, 2010) of student performances, or use of graphic representations of performances (Riley, 2005; Tomita & Barber, 2008) can assist students to understand what is going on in their performances, and also to help them to self-assess their performances (Daniel, 2001; Riley, 2005; Zhukov, 2010). Some studies showed that players became more aware of their muscular movements after receiving biofeedback or neurofeedback (see Gruzelier & Egner, 2004, for an overview), even if these additional feedback forms are used for self-study rather than in lessons alongside their teachers. However, the use of augmented feedback delivered by technology alongside the teacher feedback in piano learning and performance has rarely been explored in the music research field.

2.6 The role of augmented feedback in learning

Augmented feedback, whether in the form of KR or KP, can enhance learning. There are three possible ways that KR and KP operate to effect positive learning, and theories of learning have generally adopted one or more of these positions (see Hattie & Timperley, 2007, for an overview). Both forms of feedback, KR and KP, are considered to have '*informational*, *motivational,* and *associational* functions' (Schmidt & Lee, 2011, pp. 424-425, original emphases).

The function of information appears because:

> …when KR is not presented (on no-KR trials), subjects tend to *repeat* the given movements rather than to eliminate them. Only when KR is presented do subjects change their movements, and then quite clearly in the direction of the target. It would seem that subjects are not using the KR as a reward, but rather as *information* about what to do next (Schmidt & Lee, 2011, p. 424, original emphases).

The function of motivation appears because:

> …receiving information like KR and KP can play a strong motivating, or "energizing", role. Augmented feedback may make the task seem more interesting, keep the learner alert, cause the learner to set higher

> performance goals, and generally make boring tasks more enjoyable (Schmidt & Lee, 2011, p. 425).

Finally, the function of association appears because KR provides ‘associations between stimuli and movements’, and supplies ‘relationship between internal commands and the outcomes that were produced in the environment’ (Schmidt & Lee, 2011, p. 426).

According to Annett (1969, p. 11), feedback in the form of KR ‘is one of the most general features of all learning situations’ and ‘is a potent factor in efficient learning and in maintaining high levels of performance’. One reason for this is that KR is reported to have three functions ‘the informative function of feedback [,] and the reinforcing function [,] and incentive function of reward and punishment’ (Annett, 1969, p. 37).

Similarly, Magill (1989, p. 319) stated the following three functions of KR considered to be important for the skill-learning process: first, to guide error correction by the learner; second, to motivate the leaner; and third, to reinforce correct performance. In other words, the use of KR in learning: ‘helps to ensure the proper development of the model of correct performance by the individual’; enhances ‘the acquisition of the skill by facilitating the learning process’; and provides ‘a source of motivation for the learner’ (Magill, 1989, pp. 324-325).

Although Annett (1969), Magill (1989), and Schmidt and Lee (2011) have used different terminologies to define the functions of KR feedback, they all agree with most of the functions which also complement each other. Feedback in the form of KR functions in four main aspects. First, KR gives information to the person for error correction. Second, KR motivates the person. Third, KR reinforces a correct performance and fourth, KR promotes associations between individual internal commands and their environment.

In summary, KR contributes to the skill-learning process ‘by shortening the time needed to achieve a certain level of performance and by leading to better eventual performance' (Magill, 1989, pp. 326-327). However, there are two main guides which might determine how much and what kind of KR is adequate in order to facilitate learning. First, KR should not give too much information, otherwise the learner might feel overwhelmed and the teacher might lose effectiveness of the control of each skill being developed. Second, KR should not give too little information. The most important point seems to be that KR must be meaningful to the learner in order to promote learning (Magill, 1989; Schmidt & Lee, 2011; Welch, 1985b).

Feedback can also degrade learning. Research suggests that the frequency of feedback is important to changing behaviour. In general, providing more feedback is considered positive (Schmidt & Lee, 2011). However, when excessive feedback is given, it cannot help learning because it does not offer opportunities for the learner to use the available inherent feedback (Schmidt & Lee, 2011). Some studies suggest that 'to give KR after every practice attempt is either potentially detrimental to learning or is a waste of time' (Magill, 1989, p. 338). Two possible reasons for high-frequency KR interfering negatively in learning are that it can lead to 'an attention or working memory capacity "overload" ' and 'dependence on the KR, rather than dependence on the internal sensory feedback system for error detection and correction information' (Magill, 1989, p. 338). Thus, some types of feedback can degrade learning. For instance, frequent and immediate augmented feedback 'can *block* the processing of inherent sources of feedback' (Schmidt & Lee, 2011, p. 354, original emphasis) since it 'does not allow the learner an opportunity to work on correcting the errors that the KR has directed him or her to correct' (Magill, 1989, p. 338). Feedback can also be redundant. Sometimes KR facilitates little learning because the same information provided by KR has already been captured by the learner through their internal sensory feedback system and processes (Magill, 1989, p. 341). Apart from the roles of feedback in motor control and learning, feedback and its varied forms are crucial in educational settings as discussed below.

2.7 Feedback (and feed forward) in one-to-many learning

The positive impact that feedback can have in learning is clear. Feedback has an impact on learning in school to HE settings. The provision of feedback is a crucial aspect of ensuring learning, and improving it in learning-teaching environments (Hattie & Timperley, 2007; Hounsell et al., 2003).

Feedback can be defined in many ways as:

> information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding (Hattie & Timperley, 2007, p.81).
>
> information about how successfully something has been or is being done (Sadler, 1989, p. 120).
>
> information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way (Ramaprasad, 1983, p. 4).
>
> information in with which a learner can confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies (Winne & Butler, 1994, p. 5740).
>
> a process whereby learners obtain information about their work in order to appreciate the similarities and differences between the appropriate standards for any given work, and the qualities of the work itself, in order to generate improved work (Boud & Molloy, 2013a, p. 6).

The first definition (Hattie & Timperley, 2007) embraces the notion that feedback on student performance is usually provided by an external source, but can also be delivered by the student based on their internal feedback. The second definition (Sadler, 1989) takes into account the argument that feedback will inform how student performance is and how far or close that performance is from an ideal or a successful performance. This definition might be problematic because it seems to have prioritized the final product, in this case a successful performance, rather than the learning process according to the individual performance skills of the student. The third definition (Ramaprasad, 1983) best matches that described by Wiener (1961) by focusing on the core purpose of providing feedback, which is to bridge the gap between the intended and actual performance. In this definition the learning process is taken into account. Finally, the fourth (Winne & Butler, 1994) and fifth (Boud & Molloy, 2013a) definitions argue that the key role of students regarding feedback is an active one. Students are not only recipients of information provided by teachers but play an active role in their own self-assessment in order to improve their performances.

Feedback provided by teachers in HE ‘can have a significant impact on the motivation of a learner, both intrinsic (wanting to learn) and extrinsic (needing to learn)’ (Irons, 2007, p. i). Irons (2007, p. 1) also suggests that the ‘quality of feedback and timeliness of feedback are key features in the student learning process and in the teacher/student relationship’ even though this seems to be a major challenge that teachers encounter. In the context of HE classroom settings, ‘immediate feedback given in class following a formative task or student presentations has benefits in relation to timely feedback on performance’ (Ball et al., 2012, p. 14), particularly when ‘feedback is embedded in day-to-day learning activities’ (Ball et al., 2012, p. 9). In addition, the role of students in their own learning in HE settings has been acknowledged since ‘the learning benefits of well-designed assessment are also found when students are involved in assessment; using feedback, peer assessment and self-monitoring of progress as moments of learning in themselves’ (Ball et al., 2012, p. 10).

Ensuring effective feedback has been a challenge in learning and teaching settings since it can differ in terms of ‘the type of feedback and the way it is given’ (Hattie & Timperley, 2007, p. 81). A model of feedback based on a conceptual analysis was proposed by Hattie and Timperley (2007, p. 86) who claimed that ‘the main purpose of feedback is to reduce discrepancies between current understandings and performance and a goal’. In this feedback model, not only teachers but also students are involved in the process of giving and receiving feedback in order to use questions to identify goals (feed up), to recognise progress which has been made towards the goal (feedback), and to select activities which will need to be undertaken to achieve further goals (feed forward) (Hattie & Timperley, 2007, p. 103). In addition, feedback is mostly effective when it is given before the task, during the performance process, and through student self-regulation rather than when it is directed at the self or personal level (Hattie & Timperley, 2007).

In sum, Hattie and Timperley (2007) argued that, in order to be effective, feedback needs:

> to be clear, purposeful, meaningful, and compatible with students' prior knowledge and to provide logical connections (Hattie & Timperley, 2007, p. 104).
>
> to prompt active information processing on the part of learners, have low task complexity, relate to specific and clear goals, and provide little threat to the person at the self level (Hattie & Timperley, 2007, p. 104).

A study by Hattie (1999; cited in Hattie & Timperley, 2007, p.84) suggested that 'the most effective forms of feedback provide cues or reinforcement to learners; are in the form of video-, audio-, or computer-assisted instructional feedback; and/or relate to goals'.

In these ways, effective feedback depends on clear and specific goals in order to improve the performance of an individual by diminishing differences between intended and actual performance outcomes (Latham & Locke, 1979). In addition, effective feedback seems to foster self-regulation mechanisms and increase learner autonomy (Hattie et al., 1996).

Feedback has been frequently associated with assessment in educational settings particularly in regard to formative assessment. Assessment can be diagnostic, formative or summative in education and educational research. Assessment 'denotes any appraisal (or judgment, or evaluation) of a student's work or performance' (Sadler, 1989, p. 120). Formative assessment has been defined as 'any task or activity which creates feedback (or feed forward) for students about their learning' which does not result in a mark or grade (Irons, 2007, p. 7), and 'can be used to shape and improve the student's competence' (Sadler, 1989, p. 120). Summative assessment 'is concerned with summing up or summarizing the achievement status of a student' (Sadler, 1989, p. 120) and 'results in a mark or grade which is subsequently used as a judgement on student performance (Irons, 2007, p. 7).

From the institutional perspective, the predominance of '[s]ummative assessment […] has distorted the potential of assessment to promote learning (assessment for learning)' and has also restricted 'methods that have demonstrable value for learning, such as feedback on drafts, group assessment, peer learning and work-based assessment (assessment for learning)' (Ball et al., 2012, p. 9).

Feedback (or feed forward) has been commonly associated with formative feedback. The difference between feedback and feed forward is that feedback 'provides information to learners about where they are in relation to their learning goals' whilst 'feed forward looks ahead to the next assignment' (Ferrell & Gray, 2015, p. 1). The combination of feedback and feed forward in educational settings has been called *ipsative feedback* (Hughes, 2014) or *ipsative approaches* (Ferrell & Gray, 2015). Ipsative feedback encourages 'a longer term approach to learning by making visible the consequences of feedback and feed forward on learners' (Hughes, 2014, p. 82) by allowing teachers and students 'to acknowledge personal progress by comparing previous and current work, regardless of overall achievement' (Ferrell & Gray, 2015, p. 2).

Despite differences between these feedback terms, they share the same role of providing information to enhance performances of learners, to enhance either their current or future performances. In this way, '[a] combination of feedback and feed forward ensures that assessment has an effective developmental impact on learning (provided the student has the opportunity and support to develop their own evaluative skills in order to use feedback effectively)' (Ferrell & Gray, 2015, p. 2). Feedback, then, is meaningful when learners are able to make sense of it (Hughes, 2014, p. 39). In other words, effective feedback in learning happens when students ‘understand the meaning of the feedback statements’ and when they also ‘possess critical background knowledge’ (Sadler, 2010, p. 1).

Effective feedback involves a process whereby meaningful information is delivered not only by the teacher (Boud & Molloy, 2013b; Hattie & Timperley, 2007; Sadler, 1989; Winne & Butler, 1994), but also by student self-assessment and through their own self-regulatory skills (Hattie et al., 1996) alongside their critical background (Sadler, 2010). Feedback is provided when the actual or current performance does not match the intended or desired level of performance (Hattie & Timperley, 2007; Latham & Locke, 1979; Ramaprasad, 1983) in order to improve either current performances or future performances (Hughes, 2014; Irons, 2007; Ferrell & Gray, 2015), or a clear and specific performance goal (Latham & Locke, 1979). Apart from the effectiveness of feedback, there is evidence that individual differences of learners can also affect the way students learn.

2.8 Individual differences and learning

In motor control and learning ‘the concern is how the individuals within a group differ from each other’ (Schmidt & Lee, 2011, p. 297). Two approaches have been used to measure individual differences in motor control and learning studies: experimental and differential. In the experimental approach, it is assumed that ‘humans are not really very different from one another’ (Schmidt & Lee, 2011, p. 297). In contrast, in the differential approach it is argued that ‘the primary focus is on the differences between or among individuals’ (Schmidt & Lee, 2011, p. 298).

All individuals are characterized by motor abilities and are likely to differ in the amount of ability that they possess (Magill, 1989, p. 290). Some of the benefits of identifying abilities and their relationships to motor skills is believed to stand on the identification by the teacher of ‘the source of problems or difficulties in students’ performances’ and the prediction of 'the potential for an individual to succeed in a particular skill' (Magill, 1989, p. 292).

Another variable of individual differences, which has been reported in motor control studies, encompasses 'some definable trait that can be measured in people such as age, height, weight, gender, or ancestry' (Schmidt & Lee, 2011, p. 315). The differential approach has investigated three main areas: age differences, neurological impairment, and expert-novice differences. The effect of age in motor control and learning has been the focus of interest in the majority research studies for two main age groups, namely, from birth to teenagers and the age group above sixty-five years old. The effect of neurological impairment in movement tasks has been examined 'in people who have had damage' (Schmidt & Lee, 2011, p. 318) to the central neurosystem due to absence or alteration in the sensory feedback system, for example. Finally, when comparing players from the ageing group, for example chess players and sport players, expert players recalled information better than novice players (Schmidt & Lee, 2011).

In a similar way, an overview of the nature of individual diversity in instrumental learning was reported by Hallam (1998). Acknowledging individual differences in instrumental learning and teaching is crucial, as 'every individual is different' and brings with them 'a unique set of experiences' (Hallam, 1998, p. 51) which is in line with Schmidt and Lee (2011, p. 297). As instrumental learning and teaching traditionally happens on a one-to-one basis, in order 'to facilitate optimal learning in each individual, teachers need to have a knowledge of the nature of these differences' so that 'it would be possible to satisfy individual needs' (Hallam, 1998, p. 51). Individual differences in instrumental and vocal learning seemed to be dependent on seven factors, namely, prior levels of expertise (e.g. novice or expert), age (e.g. children, adolescents, and adults), gender (e.g. as girls or boys and women and men), ethnicity and socio-economic status, cognitive and learning styles, personality (e.g. introvert or extrovert) and individuals with impairment or special educational needs (Gaunt & Hallam, 2008; Hallam, 1998).

Individual differences seem to be dependent not only on age and gender but also on the different physiological aspects of individuals (see Gaunt & Hallam, 2008, for an overview). This can happen either in relation to human voice characteristics or in relation to different types of instruments where, for example, playing woodwind instruments depends more on the respiratory system than playing string instruments, which depend more on the synchrony of fingers, hands, arms, and body movements to produce sound (Gaunt & Hallam, 2008). Different age groups also demonstrate differences in sensorimotor abilities (Gaunt & Hallam, 2008). Individuals who present any kind of impairment (e.g. hearing, seeing, physical), or learning difficulties (e.g. dyslexia, or emotional and behavioural issues) also demonstrate their individual needs and differences in learning, particularly for musical learning (Hallam, 1998).

Different types of learning styles are also evidence of different individual learning needs. Pask (1988, p. 85, original emphasis) defined style as 'a *disposition* to adopt one class of learning strategy or one class of teaching strategy in the conversation of a tutorial', and demonstrated that 'distinctive learning strategies exist' (Pask, 1988, p. 99).

Similarly, Hallam (1995) has identified two main types of different learning styles in instrumental learning: analytic/holists and intuitive/serialists. Students who adopted the former learning style used strategies such as analyses, analogies, comparisons between contrasting ideas, and conscious and advanced planning whereas students who adopted the latter learning style used strategies such as intuition, and learning 'step-by-step' rather than planning in advance (Hallam, 1995). However, Hallam proposes a third, 'versatile' learning style when both strategies are used interchangeably according to the individual needs of students.

Felder and Silverman (1988) also classified learning styles with five dimensions: inductive/deductive, sensing/ intuiting, visual/auditory, active/reflective, and sequential/global. Several research studies have reported mismatches between learning and teaching styles, and the consequent challenge to make teaching styles fit learning styles (Felder & Silverman, 1988; Franzoni & Assar, 2008). An investigation of different learning and teaching styles and their compatibility was conducted in engineering education where it was reported that:

> Students learn in many ways—by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing and drawing analogies and building mathematical models; steadily and in fits and starts. Teaching methods also vary. Some instructors lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasize memory and others understanding (Felder & Silverman, 1988, p. 674).

Similarly, individual differences are also dependent on intrinsic or sensory feedback which involves mainly visual, auditory, and proprioceptive senses (see Section 2.4). Given that each individual pianist will listen to their own playing in particular ways, it is expected that the piano teacher and student will exhibit their individual differences in a piano lesson. When a piano student performs a piece to their teacher, the teacher will perceive the student performance in a very particular way such as by listening to the performance, or by watching the movements of the student, and perhaps in a different way from how the student will perceive their own performance. Since each individual has their own personal, experiential biography, when two people 'share' the same performance, for instance a piano teacher and their student in a lesson setting, they will experience such as perceive/feel, listen/hear, and see/watch the performance in their individual and different ways because each human brain is unique as a product of genetic potential and its developmental shaping by experience (Welch, 2006).

2.9 Variability of practice and feedback in music learning

The theory of motor control and learning of discrete movements developed by Schmidt (1975, p. 235) states that 'when the individual makes a movement that attempts to satisfy some goal, he stores four things: (a) the initial conditions, (b) the response specifications for the motor program, (c) the sensory consequences of the response produced, and (d) the outcome of that movement'. This theory was tested subsequently in two music education studies, particularly in singing learning (Welch, 1983, 1985a, 1985b), and in violin learning (Pacey, 1993).

In the first study (Welch, 1983, 1985a, 1985b), to be covered in greater detail in Section 4.11, Welch tested and applied Schmidt theory ‘in explaining the complex motor behaviour necessary for singing in tune’ with children who were considered ‘poor pitch singers’ (Welch, 1985a, p. 7). An experimental design with more than sixty children aged 7-8 years old was chosen to investigate their learning to sing a pitch in tune in different experimental conditions supported by technologically provided visual feedback, and feedback in the form of KR. Children received instructions first to listen to a ‘pitch stimulus’ and second to ‘reproduce vocally the pitch of each stimulus tone during the silent interval which followed it’ (Welch, 1985b, p. 241). The visual feedback provided a ‘visual trace of the oscilloscope’ (Welch, 1985b, p. 242), whilst KR encompassed ‘coloured lines’ which represented ‘[t]he margin of error between their attempted approximations and the stimulus tones’ (Welch, 1985b, p. 242). Findings suggested that ‘poor pitch singers’ can have their learning enhanced when these two elements are present: variability of practice or ‘use of novel vocal tasks’ such as learning activities, and KR (Welch, 1985a, p. 16).

In the second study, conducted one decade later, Pacey (1993, p. 91) tested and applied Schmidt ‘variable practice hypothesis’ in group stringed instrument learning and teaching for tasks involving dynamics (loudness), tempo, and intonation (pitch). Forty-seven children aged 8-12 years participated in groups with their teachers whilst learning the tune *Lightly Row* which was not considered to be a technically difficult piece for them. Teachers were asked to follow specific instructions in order to vary their practices. Performance outcomes of children were first audio taped, and then assessed by judges. Findings from this study indicate that variability of practice in dynamics tasks ‘by using faster, longer and slower, shorter bow lengths’ (Pacey, 1993, p. 100) seemed to be effective. However, two main conditions need to be considered when adopting the variability of practice in stringed instrument teaching with children. First, ‘pupils must not have already acquired the skill in question’ and second, ‘variable practice needs to be appropriate to the task in hand’ (Pacey, 1993, p. 100). The complex activity involved in piano learning and playing is discussed below.

Piano learning and playing is a psycho-motor activity because it involves emotional (Gabrielsson & Lindström, 2010; Juslin & Timmers, 2010; Sloboda, 2010), psychological and physiological aspects (Papageorgi & Kopiez, 2012), and embraces many complex actions at the same time, such as thinking, listening, feeling, memorizing, motor control and physical demands, perception and interpreting (Aiello & Sloboda, 1994; Dowling & Harwood, 1986; Williamon, 2004). According to Mark, Gary, & Miles (2003, p. 14):

> Playing the piano is one of the most complex of human activities. Our brains have several distinct functional areas. There is the cognitive function, which is the process of knowing and remembering; the sensory function, which governs sensation including kinaesthesia; the motor function, which controls movement; and the emotional function, which relates to feelings.

Playing an instrument or singing involves many specific functions of the human body operating at the same time. These functions may be grouped into four domains: cognition, motor control, emotion, and senses. The first function is cognition, which is used for decoding, interpreting and memorizing written music scores. The second is motor control, which encompasses moving the body, not only fingers and hands, but also the body as a whole throughout the instrumental playing or singing. The third is emotions, which relate to the feelings of the player when playing different styles of music, including communicating a particular emotion in playing the piece or one part of a piece (see Chapter 3 for further details). The fourth function of the body relates to the senses, which may be grouped into six areas: vision, audition, touch, taste, smell, and proprioceptive including vestibular apparatus. Some of these senses have a crucial role in playing an instrument and singing, as discussed below.

The first of the senses is vision, which can be focused when reading the musical score or when a performer watches their own body moving along the instrument, or peripheral when a performer sees the movement of another player when playing in an ensemble. Audition, the second sense, relates to a player listening to their own playing or performance, or that of others and the sounds of the environment and internal sounds of their body. Touch is the third sense and this relates to feeling the texture of the instrument. In piano playing, for instance, the difference materials of the keys will be noticed and whether they are ebony, ivory or plastic and if there is one uncovered ivory key, for example, the touch will be different. Similarly, if another pianist played before, this can produce a feeling that the keys are different, or greasy because of the natural oil of the fingers, or slippery because of the sweat of the hands, or the feeling of dust, which has not been removed from the piano before the performer started to play.

The fourth sense, taste, can be revealed in the ‘dry mouth’ sensation of performance anxiety. The fifth sense, smell, can relate to the smell of the player and of the environment. The proprioceptive sense is the sixth and relates to bodily movement, whilst the vestibular apparatus is responsible for balance and the stabilization of the body in stillness or in movement.

Within the six senses, vision, audition, touch, and proprioception (including vestibular feedback) seem to be the more relevant ones to have an effect on piano learning and playing. Presence, absence and alteration of these senses affect piano learning and playing, as well as memorization (see Chapter 3 for further details). The senses can also be augmented through teacher feedback in one-to-one piano lessons or the use of technology as well (see Chapter 4 for further details).

According to Welch et al. (2005, p. 229) feedback in singing is both intrapersonal and interpersonal’. Since singing and instrumental playing share similar aspects, feedback in piano playing is also likely to be intrapersonal and interpersonal. Intrapersonal feedback occurs in piano playing through the senses as visual, auditory, proprioceptive, including tactile, kinaesthetic, and vestibular feedback (Gabrielsson, 1999; Todd, 1993; Welch, 1985a).

Interpersonal feedback occurs in piano learning and teaching when feedback is given from the teacher to the student or vice-versa. Virtual interpersonal feedback in piano playing also occurs when an external source, for example technology in the form of graphical representation or a video recording, provides information about the performance to the student. This information given by an external technology source might change the nature of intrapersonal feedback of the pianist by increasing the activity of the 'internal feedback system' (Welch et al., 2005). Chapters 3 and 4 will examine intrapersonal in piano learning and playing, and interpersonal feedback in instrumental and vocal learning and teaching, respectively.

For the purpose of this thesis, the following terms are defined as follows. *Intrapersonal feedback* is related to the feedback which occurs inside an individual such as sensory feedback or other types of internal feedback related to individual internal states which are linked to the conscious-awareness state, sense of self, self-regulatory skills, metacognitive knowledge, biography and emotions. *Sensory feedback* is related to sensory information produced inside of a person when performing which includes the concomitant activity of the senses vision, audition, proprioceptive including tactile, kinaesthetic, and vestibular feedback as well as smell, and taste.

Visual feedback is the feedback produced when meaningful information about a performance can be visualized or can come through the vision sense. *Auditory feedback* is the feedback produced when meaningful information about a performance can be listened to or comes through the audition sense. *Proprioceptive feedback* includes tactile, kinaesthetic, and vestibular feedback. Proprioceptive feedback is related to the feedback produced when meaningful information about a performance can be felt by a person through their own movements statically before and/or after completing their movements, or dynamically during their movements or by a change in their proprioception. *Tactile feedback* is related to the feedback produced when meaningful information about a performance can be felt by a person through their sense of touch. *Vestibular feedback* is related to the feedback produced through the sense of self-motion and body orientation, stabilization, balance and posture. Finally, *interpersonal feedback* is related to the feedback given by an external source to an individual. An external source can be either the teacher or virtually through technology. Interpersonal feedback can be given by the teacher to the student and can also be given from the technology to the student, in order to give them meaningful information about their performance outcomes.

2.10 Summary

This chapter has addressed the concept of feedback in general and in specific areas of knowledge. Feedback is considered to be relevant to several areas of knowledge such as biology, the human body, psychology, and learning and teaching. Various types of feedback occur in biology. First, feedback inhibition for enzymological mechanisms has been reported by Gerhart and Pardee (1962) and Voet and Voet (1995). Second, feedback control for studies of attitudes and behaviour was shown by Fiske et al. (2010). Third, negative feedback for homeostatic regulation and endocrine systems was described by Campbell and Reece (2009). Fourth, positive feedback for oxytocin production in childbirth labour was shown by Campbell and Reece (2009) and Marieb & Hoehn (2007).

Feedback has been linked to error-detection and control of on-going movements in motor control and learning (Annett, 1969; Magill, 1989; Schmidt & Lee, 2011). Feed forward for anticipated information regarding prospective on-going error in movement or performance has also been reported by Schmidt and Lee (2011). Two types of feedback are considered to be present in motor control and learning: *intrapersonal feedback*, which is related to the intrinsic, inherent or sensory feedback such as vision, audition, touch, and proprioceptive sense and *interpersonal feedback*, which is related to the extrinsic or augmented feedback given by a source outside the person such as by a teacher or by technology. Schmidt and Lee (2011) suggested ten dimensions of feedback: concurrent, terminal, immediate, delayed, verbal, nonverbal, accumulated, distinct, KR and KP. KR gives information about the performance outcome and KP gives information about the movement of the performance outcome (Magill, 1989; Schmidt & Lee, 2011).

Feedback appears to enhance learning, but in some cases it may degrade learning or be redundant. Feedback appears to benefit learning because it can reinforce correct performance (Magill, 1989), motivate the learner (Magill, 1989; Schmidt & Lee, 2011), give information to the learner (Magill, 1989; Schmidt & Lee, 2011) and provide associations between internal feedback and performance outcomes (Schmidt & Lee, 2011). Feedback appears to be detrimental for learning when it is given in excess and with such high frequency that the learner does not have time to rely on their own intrapersonal feedback (Schmidt & Lee, 2011). Feedback can be redundant when it coincides and overlaps with the sensory feedback of the learner (Magill, 1989).

Interpersonal feedback can be given by teachers or coaches, and other external sources, such as technology. The main sources which have been used to give augmented feedback appear to be: videotape replays and graphic representations of performances (Magill, 1989; Schmidt & Lee, 2011). Augmented feedback in motor control and learning has also been in the forms of: video feedback, biofeedback, kinematic and kinetic feedback (Magill, 1989; Schmidt & Lee, 2011). Although video feedback provides detailed information about the performance outcomes for advanced performances (Schmidt & Lee, 2011), it appears to benefit beginners more than intermediate learners (Magill, 1989). Graphic representations of performances, conversely, appear to benefit more advanced learners than beginners (Magill, 1989). However, although all mentioned methods of giving feedback by an external source appear to facilitate learning, teacher feedback still plays an important role in learning and teaching. The implication is that a combination of teacher feedback and the use of technology may be effective in the learning process (Schmidt & Lee, 2011).

Feedback, or feed forward, is reported to be crucial in educational settings (Hattie & Timperley, 2007; Hounsell et al., 2003), since it can be provided by the teacher, the student themselves through their internal systems, and/or through an external source such as technology. Feedback in learning informs the student about any difference between their actual and a reference level of performance (Ramaprasad, 1983; Sadler, 1989), and also enhances their self-regulatory skills and metacognitive knowledge (Winne & Butler, 1994).

In instrumental playing and singing, feedback is both intrapersonal and interpersonal (Welch et al., 2005). This is because playing an instrument or singing is a psychomotor activity that involves sensory feedback such as auditory, visual and proprioceptive feedback, and instrumental or vocal learning usually involves feedback from an external source such as the teacher, and other sources such as technology. For instance, the main technological sources which have been used to give augmented feedback appear to be: video recording (Daniel, 2001), audio recording (Zhukov, 2010), graphic representation of performances (Riley, 2005; Tomita & Barber, 2008), KR and variability of practice (Welch, 1983, 1985a, 1985b), RTVF (Welch et al., 2005), and biofeedback or neurofeedback (Gruzelier & Egner, 2004). In addition, individual differences in psychomotor abilities, and music skills among learners should be considered, as should learner biography. In Chapter 3, the main points of intrapersonal feedback in piano learning and playing are examined.

3 Literature review: intrapersonal feedback

3.1 Introduction

Chapter 3, the second of three literature review chapters, introduces the concept of intrapersonal feedback in piano learning and playing. This chapter focuses on reviewing recent intrapersonal feedback studies. Intrapersonal feedback is addressed in terms of sensory feedback in its various forms, namely: auditory, visual and proprioceptive, including kinaesthetic, tactile as well as vestibular, feedback. The role of auditory, visual and proprioceptive feedback in piano learning, performance and also memorization, and synchronization in piano duo performances are reviewed. Their roles and the relationships between them are reported through studies which have focused on alterations or suppression of one or two types of sensory feedback and their effect on piano learning and playing. In addition, how the brain functions, the roles of conscious-awareness, self-regulatory skills, including self-efficacy beliefs, and metacognitive knowledge as intrapersonal feedback in music performance and learning are discussed. A model of intrapersonal feedback is proposed to demonstrate the main aspects involved in piano playing. Chapter 4 presents a detailed review of interpersonal feedback between teachers and students in piano learning alongside the application of technology-based feedback in instrumental and vocal learning.

3.2 Intrapersonal feedback in piano learning and playing

Several studies have investigated the relationship between sensory feedback and music learning and musical performance. These include studies of auditory feedback (e.g. Finney, 1997; Finney & Palmer, 2003; Furuya & Soechting, 2010; Repp, 1999), auditory and visual feedback (Banton, 1995; Wöllner & Williamon, 2007), and proprioceptive with reference to kinaesthetic feedback (Wöllner & Williamon, 2007) and tactile feedback (Goebl & Palmer, 2008). Each study was designed to understand how sensory feedback was used by performers in selected tasks, including music sight-reading, music learning, memorization, and musical performances. In addition, studies in neuroscience and music demonstrate increased interest in understanding the brain activity of musicians, such as in pianists (Parsons, Sergent, Hodges, & Fox, 2005; Stewart, 2008; Stewart & Williamon, 2008).

3.3 The role of auditory feedback in piano learning and playing

The role of auditory feedback in piano learning and playing has been mostly investigated by comparing solo performances with self-auditory feedback and with removed or altered auditory feedback in terms of pitch, timing or both, or by removing auditory feedback produced by the performance of the partner in piano duets. Some studies solely investigated the role of auditory feedback (Finney, 1997). Others examined the relationship between auditory and visual feedback (Banton, 1995; Finney & Palmer, 2003; Repp, 1999) and auditory and proprioceptive feedback (Furuya & Soechting, 2010; Goebl & Palmer, 2009). Most of these studies were conducted in the USA, Canada, France and the UK with pianist participants playing on digital pianos with or without weighted keys connected with a computer via MIDI interface.

Finney (1997) investigated the effects of perturbations of self-auditory feedback in piano performances in the USA. Pianists were asked to play two musical excerpts of a piece by Bach on a velocity-sensitive electric keyboard under five different conditions: full presence of auditory feedback, full removal of auditory feedback so participants could not hear their performances and altered auditory feedback in terms of pitch or timing delay or both. Findings of this study demonstrated that delayed auditory feedback led to significant impairment in piano performance. Conversely, pitch alteration in auditory feedback did not appear to impair piano performances.

Banton (1995) conducted an experimental study in the UK to evaluate whether auditory and visual feedback removal might influence sight-reading in piano performances. Fifteen pianists of different levels of experience in sight-reading were asked to sight-read three short musical excerpts on an electric keyboard linked to a computer via MIDI under three different conditions: both visual and auditory feedback included, visual feedback removed and auditory feedback removed. The melodic and rhythmic accuracy of the recorded performances was compared in all three conditions for the same pianist and across all pianists with regard to their errors. No significant difference was found between the presence and absence of auditory feedback for sight-reading in piano performances. Findings also indicated that visual feedback in sight-reading is more important than the role of auditory feedback for pianists who had less sight-reading experience because they depend on watching their hands and the piano for movement accuracy.

Repp (1999) examined the role of auditory feedback on ‘parameters of expression in piano performances’ (Repp, 1999, p.409) such as timing, dynamic and pedalling in two experiments in the USA. In the first experiment, skilled pianists performed a short musical excerpt from a piece by Chopin on a digital piano whilst being recorded on a computer via MIDI with and without auditory feedback. This was investigated under two conditions: playing with expression, and playing with a strict tempo set by a metronome. In the second experiment, the recorded performances were judged by listeners in order to investigate whether expression in piano performance is altered by removal of auditory feedback. Timing variations appeared to be greater in the expressive performances than in the metronomic performances. Furthermore, a significant decrease of frequency in pedal changes was observed in performances without auditory feedback. Findings suggested that auditory feedback removal did not interfere significantly with accomplished expressive piano performances in relation to timing and dynamic. However, it was suggested that ‘normal auditory feedback is vitally important in learning a piece, refining its interpretation, and fine-tuning a performance’ (Repp, 1999, p. 434). The limitations of this experiment are twofold. First, the genre of music might affect the parameters of expression investigated in this experimental study. For example, a romantic piece involves a more complex set of musical performance parameters such as touch and resonance than classical or baroque pieces. Second, the use of a digital piano might also affect findings. Although an acoustic piano is customarily used in conventional piano performance settings, a digital piano is likely to be used in replacement of the acoustic piano for where specific and detailed data measurements are required electronically. Thus, the decision concerning the choice of repertoire and digital piano needs to be acknowledged since these two factors might have an effect on the performance and subsequently on the findings of this investigation.

Three piano-learning and memorization experiments conducted in the USA investigated the effects of auditory feedback on unfamiliar and well-learned piano pieces (Finney & Palmer, 2003). Thirty-one participant pianists were asked to play on an electric keyboard with weighted keys linked to a computer via MIDI. In the first experiment, the presence or absence of auditory feedback was examined in the learning and later memorization of four short unfamiliar piano pieces. The second experiment investigated the extent to which proprioceptive and auditory feedback can influence the musical learning of a short piano piece and its recall. The third study evaluated the role of auditory feedback in well-learned pieces performed from memory. Findings from the two first experiments suggested that auditory feedback might have significant positive effect on musical learning in terms of the later recall of short and unfamiliar music pieces. Results from the third experiment indicated that the absence of auditory feedback in the performance of a well-learned musical repertoire did not disturb recall of these pieces (Finney & Palmer, 2003).

The role of auditory feedback and its effects on proprioceptive feedback in a solo piano performance and a piano ensemble were also examined in several studies (Furuya & Soechting, 2010; Goebl & Palmer, 2009). The influence of auditory feedback on keystroke production in piano playing was reported in a USA study (Furuya & Soechting, 2010). Pianists were asked to play on a digital piano (connected to a computer via a MIDI interface) three short pieces in three different tempi, such as slow, moderate and fast, under four different conditions: normal conditions, altered auditory feedback conditions in timing, pitch and dynamics or loudness. In order to understand the extent to which auditory feedback perturbations interfered with keystroke production, the researchers measured ‘finger-key contact duration, inter-keystroke interval, and keystroke velocity' (Furuya & Soechting, 2010, p. 226), and then made comparisons between altered and normal performance conditions. Findings showed that keystroke production can be changed by alteration of auditory feedback in terms of timing, pitch and dynamics or loudness. Whilst modification of timing or pitch of the tone appeared to increase the velocity of the keystroke, a perturbation in loudness or dynamics of the tone did not appear to follow a pattern of alteration in the keystroke velocity.

In another study conducted in Canada, Goebl and Palmer (2009) investigated the effect of full or partial removal of auditory feedback in a piano duet performance. Pairs of pianists, a leader and follower, were asked to perform three specially created duet pieces on a digital piano. Note timing in terms of temporal accuracy and finger and head movement were measured in order to evaluate synchronization of the two pianists under four different auditory conditions: feedback to both leaders and followers; feedback to leaders of themselves only; feedback to followers of both leaders and followers; and self-feedback to leaders and followers. Findings indicated that partial suppression of auditory feedback increased timing variability in piano duet synchronization, particularly in note attack and release. To compensate for the absence of full auditory feedback, pianists were found to exaggerate finger and head movements. This augmenting of visual feedback aimed to achieve synchronicity when the pianists played alongside each other. The role of visual feedback in piano learning and playing is discussed below.

3.4 The role of visual feedback in piano learning and playing

The role of visual feedback has been investigated in solo piano sight-reading (Banton, 1995) and piano duo coordination (Bishop & Goebl, 2015; Kawase, 2014) by removing or manipulating visual feedback. Restriction of views of the keyboard and the self-movement of hands and the head movements and gaze of the partner exemplify visual manipulation. As reported above, the removal of visual feedback has been shown to interfere with the performances of less experienced pianists if they are not allowed to see the keyboard and the movements of their hands when sight-reading an unfamiliar piece, even if they are allowed to see the music score (Banton, 1995).

The role of visual feedback in duo performance synchronization was investigated in a study by Bishop and Goebl (2015). Thirty-one pianists participated by playing on a Yamaha Clavinova the secondo part of three duet pieces by Satie, Mendelssohn, and Schytte whilst accompanying audio and video recordings of pianists or violinists playing the primo part. The study examined the effect on the follower pianist in five different feedback conditions: full auditory feedback only, partner-auditory feedback only, self-auditory feedback and other-visual feedback, other-visual feedback only, and normal conditions, which provided a baseline. Findings suggested that the absence of secondo pianist self-auditory feedback did not seem to disturb synchronization in a duo performance. In contrast, in the absence of auditory feedback from primo musicians, secondo pianists relied on visual feedback in the form of the head and body movements of primo musicians in video recording so as to synchronize the duo performance. Overall, it was found that under normal conditions '[p]iano-piano duos synchronized more precisely than piano-violin duos' whilst in the absence of primo musician auditory feedback synchronization of piano-piano duos were less precise than violin-piano duos (Bishop & Goebl, 2015, p. 18). Findings also demonstrated that visual feedback is essential to secondo pianists because it provides 'important information at times when co-performers' intentions are otherwise difficult to predict' (Bishop & Goebl, 2015, p. 19). In addition, the synchronization also seemed to depend on '[a] combination of factors, including performance experience, similarity in performers' playing styles, and the clarity of gestures produced by primos' (Bishop & Goebl, 2015, p. 19).

The role of visual feedback in newly formed piano duos was investigated by Kawase (2014) by looking at the effect of gazing cues in piano duo coordination. Professional pianists were asked to play a particular piece with several variations in tempo on digital pianos in two soundproofed rooms separated by a window so that while visual feedback was available, they had full removal of auditory feedback as a normal condition baseline. The piano duos were asked to perform alongside each other in normal conditions with full visual feedback but without auditory feedback, and three other altered conditions: full or partial removal of visual feedback of the body or head movements of the partner. Findings suggested that synchrony between two pianists when playing together was higher when there was either full or partial visual feedback of the partner. Full removal of visual feedback of the partner was found to interfere with the piano duo synchronization. The role of head movement was also investigated in this study under two conditions: restricted and free head movement. Findings suggested that: first, 'mutual gaze is important for reducing timing lag between performers'; second, 'mutual gaze modulates remarkable and arbitrary temporal expressions, such as fermata'; and third, 'performers may utilize movements as visual cues for strict synchronization' (Kawase, 2014, p. 527). How other sensory feedback influences piano learning and playing is reviewed below.

3.5 The role of proprioceptive feedback in piano learning and playing

Several studies have investigated the role of proprioceptive feedback, which includes tactile and kinaesthetic feedback, in piano playing when manipulating other types of sensory feedback such as auditory or visual feedback (Brown & Palmer, 2012; Wöllner & Williamon, 2007), and manipulating proprioceptive feedback through playing at different tempi (Goebl & Palmer, 2008, 2013). Proprioceptive feedback also encompasses implicitly vestibular feedback in piano learning and playing since it relates to self-motion, orientation, posture and motor control as reported by Cullen (2012) in Chapter 2 (see sections 2.4 and 2.9), even if there are no experiments testing its role directly in this context.

The role of auditory and proprioceptive feedback in auditory memory recognition of short melodies recently learned by trained pianists was studied by Brown and Palmer (2012) in Canada. Pianists were asked to learn melodies under four feedback conditions whilst playing on digital pianos with weighted keys. The first condition was with auditory feedback only, such as listening to the melody without making any finger movement. The second condition was only with proprioceptive feedback, for example playing the melody without being able to listen. The third condition was with both self-auditory and proprioceptive feedback as a normal condition. Finally, the fourth condition was with proprioceptive and other-auditory feedback, such as playing and listening to a computer-generated recording instead of their own performance outcomes. Having completed these initial tasks, the pianists were asked to recognize the melodies by listening to computer-generated recordings whilst reading the scores. Findings suggest that recognition of melodies was higher when melodies were learned with both auditory and proprioceptive feedback—as under normal performance conditions—rather than when melodies were learned with only auditory feedback. This implies that 'strong auditory-motor coupling aids learning by facilitating the formation of auditory-motor associations' (Brown & Palmer, 2012, p. 577). These findings support reported neurological studies of the arcuate fasciculus (Halwani, Loui, Rüber, & Schlaug, 2011; Moore, Schaefer, Bastin, Roberts, & Overy, 2016) which links auditory and motor areas, such as in professional singers whose 'long-term vocal-motor training might lead to an increase in […] sound perception, production, and its feed forward and feedback control which can be differentiated from a more general musician effect' (Halwani et al., 2011, p. 1).

The relationship between sensory or 'performance feedback' such as auditory, visual and kinaesthetic feedback, and mental imagery in piano performance was also studied in the UK (Wöllner & Williamon, 2007). In this study, expert pianists were asked to perform from memory on a Yamaha Disklavier with a silent system one piece of their current repertoire from the Baroque to Classical periods. The selected piece was played without sudden tempo changes under four different and diminishing performance feedback conditions. The first condition was the removal of visual feedback where players were unable to see their hands and the keyboard while playing. The second condition was the removal of auditory feedback where players were not able to hear what they were playing. The third condition was altered kinaesthetic feedback where players were not allowed to play the piano, but were asked to tap the beat for the entire piano piece while imagining their performance.

The final condition was under normal conditions where players had full performance feedback. According to the authors, performance feedback in the form of auditory, visual and proprioceptive feedback ‘enables pianists to control individual aspects of their performance plans, such as nuances in the expressive timing and intensity microstructure’ (Wöllner & Williamon, 2007, p. 40). For that reason, expressive timing and loudness or dynamic deviations were used to compare the performances under all four conditions. The performance with full feedback was defined as the reference condition. Findings demonstrated that altered kinaesthetic feedback significantly affected the piano performances when compared to the removal of either auditory or visual feedback. One limitation of this study might be the condition of relying on tapping the beats as an indicator of a consistent performance produced by the mental imagery of the pianists. Although half of the pianists showed consistent performance under the altered kinaesthetic feedback condition, individual differences between participants might also have been a determinant factor in this study (Wöllner & Williamon, 2007).

The role of tactile feedback in timing accuracy in piano playing was investigated in a study in Canada (Goebl & Palmer, 2008). Pianists were asked to play an isochronous sixteen-tone melody at different tempi such as slow, moderate and fast. Tactile feedback in this study relates to finger-key contact, strike and pressure regarding kinematic variables such as the velocity and acceleration of skilled-pianist finger movement in performances. Timing accuracy was studied in terms of these kinematic variables. Results demonstrated that some pianists ‘showed a positive relationship between increased tactile feedback and increased temporal accuracy for the upcoming keystroke’ when performing at a slow rate (Goebl & Palmer, 2008, p. 477). Furthermore, the authors relate this finding to the greater freedom pianists might have to plan finger movements and trajectories for a slow performance when compared to a fast performance. The next section summarizes and develops a wider perspective on the role of intrapersonal feedback in piano learning and playing.

3.6 Overall roles of auditory, visual and proprioceptive feedback in piano studies

The role of intrapersonal feedback in solo piano learning, performance, and memorization as well as ensemble performance synchronization has been investigated in several experimental studies. Full or partial removal or alteration of auditory, visual, and proprioceptive feedback studies have contributed to more nuanced understandings of piano leaning. Most investigated intrapersonal feedback in piano learning seems to be auditory feedback followed by visual, and then proprioceptive feedback.

In broad terms, auditory feedback may not play a significant role for expert and skilful pianists performing familiar and well-known solo pieces. More specifically, research has shown that auditory feedback may not play a significant role for expert and skilful pianists in terms of sight-reading piano pieces (Banton, 1995), automated piano performances regarding timing and dynamic variations (Repp, 1999), performances of long-term and well-learned piano pieces (Finney & Palmer, 2003; Wöllner & Williamon, 2007), guiding the mental image of a piano piece (Wöllner & Williamon, 2007), and automated piano performances for expert pianists with regard to pitch alteration (Finney, 1997).

In solo piano playing, manipulation of auditory feedback seems to impact on piano learning and performance under certain experimental conditions. Delayed auditory feedback for timing interferes with piano performance (Finney, 1997). Delayed timing and alterations of pitch and loudness affect proprioceptive feedback such as keystroke production in piano performances (Furuya & Soechting, 2010). Removal of auditory feedback interferes with piano learning and memorization of unfamiliar pieces (Finney & Palmer, 2003), and impairs pedalling in piano performance (Repp, 1999).

The role of visual feedback, in contrast, has been scarcely reported in comparison with the role of auditory feedback, especially with regard to solo piano studies. Visual feedback in terms of watching hand movements and the keyboard are reported to be essential in piano sight-reading. In solo piano learning and playing, removal of visual feedback impairs piano sight-reading especially for less trained pianists (Banton, 1995). In contrast, removal of visual feedback did not affect well-learned solo piano performances (Wöllner & Williamon, 2007). In duet performance synchronization, visual feedback plays a crucial role in respect of head and body movements of the partner and mutual gaze between players to compensate for full or partial removal of auditory feedback (Bishop & Goebl, 2015; Goebl & Palmer, 2009; Kawase, 2014). However, the role of nature and quality of visual feedback in piano learning and playing still needs to be explored.

The role of proprioceptive feedback alongside auditory feedback is crucial in piano learning and recall of learned unfamiliar melodies, which implies auditory-motor associations in piano playing (Bishop & Goebl, 2015; Brown & Palmer, 2012; Halwani et al., 2011; Moore et al., 2016). Altered proprioceptive feedback such as tapping instead of playing interfered more with piano performances than removed visual or auditory feedback (Wöllner & Williamon, 2007). Proprioceptive feedback in terms of keystroke or finger, hand, wrist, and forearm movement vary with different tempi of piano pieces and across individual pianists (Goebl & Palmer, 2008).

In performance ensembles, removal of self-auditory feedback did not seem to play a crucial role, and did not disturb synchronization in a duo performance (Bishop & Goebl, 2015). Absence of partner auditory feedback seemed to interfere with temporal synchronization between pianists (Bishop & Goebl, 2015; Goebl & Palmer, 2009). Perturbations of auditory feedback in terms of timing, pitch, and dynamics or removal of partner auditory feedback alters proprioceptive feedback in solo piano playing and in duo synchronization in terms of finger movements such as keystroke, note attack and release as well as the head and body movements of both players, respectively (Furuya & Soechting, 2010; Goebl & Palmer, 2009; Kawase, 2014). In the absence of partner auditory feedback, performers relied on partner head and body movement (Bishop & Goebl, 2015) or mutual gaze (Kawase, 2014) in order to synchronize or reduce timing lags between players, especially when the intentions of the other player are unclear (Bishop & Goebl, 2015). Thus, visual feedback plays a crucial role in the absence of auditory feedback whilst removal of both interferes with proprioceptive feedback in piano learning and playing. Brain functions in piano studies are discussed below.

3.7 Brain activity in piano learning and playing

Researchers have looked at brain activity of pianists under various conditions in order to understand how their brains work in piano learning and playing. Thus, intrapersonal feedback also encompasses brain activity of pianists since it happens inside of the individual, besides the fact that brain functions of musicians differ from non-musicians as well. There is evidence through brain scans that brain activity of pianists may reveal associations between auditory, visual and proprioceptive feedback when they learn and play under certain conditions.

Several studies relate neuroscience and music performance, music learning and music cognition (see Stewart & Williamon, 2008, for an overview). Some studies have used neuro-scientific approaches to understand musical performance in the components of 'perception, sight-reading, motor-sensory processes and attention' (Parsons et al., 2005, p. 199). Other studies have addressed differences in brain function between musicians and non-musicians, early and late-trained musicians, and musicians with different instruments, in motor and somatosensory maps, and in auditory and visual-motor processing (e.g. Mathias et al., 2015; Pfordresher, Mantell, Brown, Zivadinov, & Cox, 2014).

Brain responses were examined in a study in the USA when alteration of auditory feedback was undertaken in trained pianists when learning and memorizing five-note melodies (Pfordresher et al., 2014). The brains of pianists were scanned through magnetic resonance imaging whilst they were playing from memory recently learned melodies under five conditions: no self-auditory feedback as a silent performance condition, self-auditory feedback such as normal performance condition, altered auditory feedback for asynchrony, altered auditory feedback for random pitch, and altered auditory feedback for pitch such as transposed melody. Findings from the brain imaging suggested that different parts of the brain were activated according to the different conditions, thereby providing ‘the first evidence of neural responses associated with perception/action mismatch during keyboard production’ (Pfordresher et al., 2014, p. 28). Findings demonstrated that ‘alterations of auditory feedback during performance that lead to asynchronies between actions and sound lead to a distinct pattern of disruption and are associated with distinct neural activation patterns’ (Pfordresher et al., 2014, p. 34).

The role of the sensorimotor system in recognizing learned melodies was also investigated in a study conducted in Canada and France (Mathias et al., 2015). This study encompassed the learning stage of a piano piece and the memory recognition stage. In the first phase, pianists were asked to learn piano pieces under two conditions: first, through auditory feedback only, whereby pianist learning was meant to happen by listening to a recorded performance of the piece, and, second, through both auditory and proprioceptive feedback where pianist learning was meant to happen by playing the piece. In the later memory recognition stage, the pianists had their brain activity recorded through electroencephalography whilst they were listening to the piano pieces that they had learned under the two different conditions. Findings suggest that there is an effect of coupling auditory-proprioceptive feedback when accomplishing memory recognition of recent learned piano pieces in the learning by playing and listening condition. The auditory-motor coupling was not evident when accomplishing memory recognition of pieces in the learning only by listening condition. Results show positive links between perception and production since ‘[p]roduction experience increased recognition of learned musical melodies above and beyond recognition rates achieved following listening-only experience’ (Mathias et al., 2015, p. 2251). The outcomes also reveal that ‘auditory-motor interactions contribute to memory benefits conferred by production experience, and support a role of motor prediction mechanisms in the production effect’ (Mathias et al., 2015, p. 2238). This finding links to a previously reported piano-related study which investigated the role of combined auditory and proprioceptive feedback in recognizing short and recently learned melodies by skilled pianists (Brown & Palmer, 2012), and with the previously reported neurological studies which examined the links between auditory and motor areas in musical performance (Halwani et al., 2011; Moore et al, 2016).

3.8 Conscious-awareness as intrapersonal feedback

Intrapersonal feedback involves several internal processes such as auditory, visual and proprioceptive feedback, and also becoming conscious-aware. In the previous sections it was discussed that piano performances depend on the coupling in auditory-visual-proprioceptive feedback processes, since removal or perturbation of one type of sensory feedback was reported negatively to affect piano learning, performance and recall. Piano learning also involves understanding musical performance parameters such as musical structure, melodic and rhythmic accuracy, timing, and dynamic contrast. It is argued that intrapersonal feedback in piano learning and playing also encompasses different levels of conscious-awareness. One level might be related to becoming aware of the internal states of the body such as auditory, visual and proprioceptive feedback through playing or listening. Another level might be related to becoming aware of musical performance parameters which are related to the musical notation and performance. Thus, intrapersonal feedback may also include conscious-awareness, which can be developed through interpersonal feedback, and be dependent on individual differences across pianists.

The term ‘conscious-awareness’ brings the complex relationships between ‘social, emotional, biological, and cultural aspects’ of individuals in the musical performance activity (Acitores, 2011, p. 225). Relevant contributions to understandings of consciousness and its relationships with perception, action, emotions, and memory have been made by neuroscience studies (Damasio, 2012; Edelman, 2001; Gallese, Keysers, & Rizzolatti, 2004). In addition to these comprehensive views of conscious-awareness in neuroscience studies, Acitores (2011, p. 223) argues that conscious-awareness in music is based on proprioceptive feedback when stating that 'consciousness is based on the body' and 'the feeling of the body is possible through proprioception' (Acitores, 2011, p. 215). However, some theories classified different levels or types of conscious-awareness as discussed below.

Edelman (2001) proposed a theory which defined two distinct levels of conscious-awareness: 'primary consciousness' and 'higher-order consciousness'. Primary consciousness was defined as 'the state of being mentally aware of things in the world' (Edelman, 2001, p. 113) which involves perception through the senses such as visual, auditory, touch, smell, taste, and proprioception. Higher-order consciousness refers to 'the recognition by a thinking subject of his or her own acts or affections' (Edelman, 2001, p. 113) which involves 'perception of the self' (Acitores, 2011, p. 215) within intrapersonal feedback (Acitores, 2011; Edelman, 2001). Similarly, Damasio (2012) has proposed two main types of conscious-awareness alongside the sense of self.

Damasio (2012) recognizes two main types of consciousness described as minimal-scope and big-scope. Minimal scope consciousness, namely, '*core* consciousness' involves 'the sense of the here and now', whilst big-scope consciousness, namely '*extended* or *autobiographical* consciousness', is evident 'when a substantial part of one's life comes into play and both lived past and the anticipated future dominate the proceedings' (Damasio, 2012, pp. 168-169, original emphases). Underpinned by the definition of consciousness as '*a state of mind in which there is knowledge of one's own experience and of the existence of surroundings*' (Damasio, 2012, p. 158, original emphases), Damasio (2012, p. 161) recognized three indispensable conditions of consciousness, '(1) to be awake; (2) to have an operational mind; and (3) to have within that mind, an automatic, unprompted, undeduced sense of self as protagonist of the experience'. In addition, Damasio (2012, p. 169) points out that 'levels of consciousness fluctuate with situation'.

Other internal processes, for instance the mirror neuron system, also seem to support intrapersonal feedback in piano learning and playing since it involves action through the motor-control processes and as well as emotion. Gallese et al. (2004, p. 396) claimed that the mirror neuron system in the brain enables individuals ‘to directly understand the meaning of the actions and emotions of others by internally replicating (‘simulat-simulating’) them without any explicit reflective mediation’. The evidence for understanding actions is that when one individual watches another individual performing a movement which they had previously experienced, the brain regions related to movements of the individual who watches are activated in the same way as if they were actually performing.

In the field of neuroscience, Jeannerod (2006, p. 25) suggested that individuals might not be conscious of their actions or performances because ‘even when an action is consciously executed, its memory trace is of a very short duration, and so it is rapidly forgotten’. Jeannerod (2006, p. 25) argued that individuals only have consciousness of actions when they are ‘aware of the goal’ and ‘how that action is (or was) performed’. Becoming conscious of actions or aware of performance goals seems to be a post-hoc phenomenon because ‘consciousness appears to be bound to a posteriori signals arising from the completion of the action itself, not to central signals that precede the action’ (Jeannerod, 2006, p. 36).The implication of this statement for this current study is that piano students can become more conscious of their actions after performing as a post-hoc phenomenon rather than before or during the piano performance. One of the arguments of this study is that conscious-awareness of performances might be enhanced by using technology, which can enable individuals such as piano students and teachers access to their practice/performance at any time as a post-hoc phenomenon.

In the field of music research, Lahav, Saltzman, & Schlaug (2007, p. 308) reported that the human mirror neurons system seemed to be ‘involved not only when observing actions but also when listening to action-related sound’. In the first stage of this study, non-musician participants were asked to learn a five-key piano melody for the right hand only, in five days by imitation, for instance by listening to and playing the melody. The second stage of this study encompassed a functional magnetic resonance imaging brain scan of the same participants whilst they were listening to the recently learned piano piece. The third stage, brain scanning took place of participants whilst they were listening to familiar pieces which they had not learned to play, and which provided the control condition. Findings revealed that sound-action related brain regions were activated when participants were listening to recently performed piano pieces and as they were actually playing the piece, while only sound-related brain regions were switched on when participants listened to familiar but not learned music pieces (Lahav et al., 2007). Findings of this study are also in line with those of previously reported studies which showed evidence of auditory-proprioceptive coupling in the brain activity of pianists when they learned piano pieces through playing by using auditory and proprioceptive feedback (Brown & Palmer, 2012; Halwani et al., 2011; Mathias et al., 2015; Moore et al., 2016).

Conscious-awareness of musical performance might be related to the multiple couplings of the sensorimotor system, such as visual-motor awareness and auditory-motor awareness (Acitores, 2011; Edelman, 2001; Lahav et al., 2007; Mathias et al., 2015). In this way, in one-to-one piano learning and teaching environments, when students observe the sound and motor actions produced by their teachers when playing a piece that students had already experienced playing, students might be more conscious of their auditory and proprioceptive feedback than when they observe the playing of an unfamiliar piece. In addition, students might be more conscious of their own performances not only through their auditory feedback, but also through their proprioceptive feedback when they listen to their own recorded performances which had been learned previously. Conscious-awareness in piano learning might have an impact on the way in which students self-evaluate themselves through more reflective and critical thinking. The roles of self-regulation and metacognitive knowledge in music learning are discussed below.

3.9 Self-regulation, and metacognition in music learning and performance

Self-regulation and metacognitive knowledge play important roles in learning environments. Self-regulation was defined by Zimmerman (2001, p. 5) as 'the purposive use of specific processes, strategies or responses by students to improve their academic achievement'. The relationship between feedback and self-regulation in learning shows that effective feedback 'is powerful to the degree that it leads to further engagement with or investing further effort into the task, to enhanced self-efficacy, and to attributions that the feedback is deserved and earned' (Hattie & Timperley, 2007, p. 102).

In a recent review of self-regulation, learning and performance, Zimmerman (2011, p. 49) argued that '[s]tudents are self-regulated to the degree they are metacognitively, motivationally, and behaviorally active participants in their own learning processes'. The model of self-regulated learning proposed by Zimmerman (1998, p. 2) involves an 'open-ended process that requires a cyclical activity on the part of the learner that occurs in three major phases: forethought, performance or volitional control, and self-reflection'. Zimmerman (1998, pp. 3-4) pointed out that there are several corresponding sub-processes for each of the three major phases for self-regulated learning. First, the forethought phase included goal setting, strategic planning, self-efficacy beliefs, goal orientation, and intrinsic interest. The performance phase involved attention focusing, self-instruction/imagery, and self-monitoring. The self-reflection phase encompassed self-evaluation, attributions, self-reactions, and adaptivity. In the forethought phase, there is the concept of self-efficacy belief described by Bandura (1997, p. 11) as being 'concerned with judgments of personal capability' and it relates to the view that students have of themselves in performing well.

Self-regulating learning strategies in the field of music were investigated by Nielsen (2001) when observing videotaped sessions of instrumental practice by two advanced level organ students in HE. Musical practice of a chosen repertoire was captured alongside the comments of students during and after their practice. Findings indicated that HE organ students demonstrated ‘extensive self-regulatory skill that enabled them to optimise their learning and performances taking into account interpersonal, contextual and intrapersonal conditions’ (Nielsen, 2001, p. 155). During practice and performance, HE students appeared to have used metacognitive competence, since they self-evaluated their performance progress by comparing their intended and actual performance outcomes as described by Nielsen (2001) when arguing that ‘the students compared the present performance with the specific goal (e.g. their idea of the final performance of the piece)’ (Nielsen, 2001, p. 164). Outcomes of this study imply that HE instrumental music students have ‘skilful self-regulatory learning’ (Nielsen, 2001, p. 155) which enables them to engage in the cyclical activity proposed by Zimmerman (1998). In this way, advanced instrumental and vocal students have the potential to develop their self-regulated learning when they demonstrate: self-evaluation and setting of specific goals, and undertake strategic planning, self-instruction, and self-monitoring (Nielsen, 2001).

Self-regulatory skills are not only part of the performance practice of HE instrument students, but also crucial in their learning process. McPherson and Renwick (2011, p. 241) maintain that, for musical instrument students, self-observation and self-control are ‘two processes that […] enable learners to optimize their performance […] while actively engaged in a problem-solving episode, such as attempting a run-through of a difficult section of a piece’. They explain the importance of self-regulation skills in musical instrument learning:

> Like any academic or motor task, learning a musical instrument requires a great deal of self-regulation. For skill on an instrument to develop optimally, young musicians need to learn how to utilize many varied behaviors to improve their performance (McPherson & Renwick, 2011, p. 235).

Hallam (1997, 2001) also argued that musical instrument performers might regulate and control their musical practice and performances through metacognition. However, McPherson and Renwick (2011, p. 241) suggested that there is ‘limiting metacognitive monitoring to key processes or outcomes, as too much monitoring can interfere and disrupt one’s performance’.

Metacognition is not only related to practice and performance, but to learning. Metacognition refers to ‘thinking about thinking’ (McPherson & Zimmerman, 2002, p. 336) and ‘the ability to reflect upon, understand, and control one’s learning’ (Schraw & Dennison, 1994, p. 460). Schraw and Dennison (1994, p. 460) also reviewed recent studies (Garner & Alexander, 1989; Pressley & Ghatala, 1990), and found that ‘metacognitively aware learners are more strategic and perform better than unaware learners’ learning’ perhaps because ‘metacognitive awareness allows individuals to plan, sequence, and monitor their learning in a way that directly improves performance’. For example, metacognitive knowledge can involve knowledge about self and about strategies and how, why and when to use these strategies. However, it is unclear whether ‘metacognition must be conscious in order to represent higher-order processing’ or involve a ‘less conscious processing […] by nature’ (Veenman et al., 2006, p. 6). Self-regulation and metacognition alongside auditory, visual, and proprioceptive feedback, and conscious-awareness forms the intrapersonal feedback in piano learning and playing which model is proposed in the next section.

3.10 A model of intrapersonal feedback in piano learning and playing

In terms of the thesis focus, which is the investigation of the pedagogical use of additional feedback generated by technology in an HE piano studio, intrapersonal feedback in piano learning and playing is multifaceted. Specifically, intrapersonal feedback embraces auditory, visual, proprioceptive and vestibular forms of feedback. It is argued that intrapersonal feedback also includes other internal processes such as self-regulatory skills, metacognitive knowledge and conscious-awareness. Auditory feedback in piano playing is related to hearing the music played, hearing the sounds produced by changes of pedalling and the keyboard mechanism inside the piano, hearing the sounds from within the body of the pianist, as well as sounds from the environment including any audience present such as the teacher. Visual feedback in piano playing is related to seeing and reading or sight-reading the music score, seeing the instrument including the piano keyboard, seeing the environment and ambient lighting, seeing their own fingers, hands, arms, and wrist movements, and the movements of others such as those of the audience.

Proprioceptive feedback encompasses all forms of kinaesthetic, tactile, and vestibular feedback. Kinaesthetic feedback involves the sense of movement itself. Tactile feedback in piano playing involves the information the body receives when the body touches an object, for example when fingers touch the keys, feet touch the pedals, and the sense from the lower body when the pianist is seated on the piano stool. Vestibular feedback involves the sense of balance, stabilization, posture, and self-motion when playing the piano which is also multimodal and integrated with other-than-vestibular types of feedback such as visual, proprioceptive, and perhaps auditory feedback. Proprioceptive feedback in piano playing incorporates any sense of movement produced by the body when pressing the pedals down or releasing them, when playing the keys, when moving the hands, arms, head, and whole body. In conclusion, auditory, visual, and proprioceptive forms of feedback appear to be the most crucial types of sensory feedback in piano learning and playing.

Self-regulation skills are a crucial component for advanced level piano students when practicing piano repertoires on their own as self-observation, and self-monitoring assist pianists in optimizing their performance. Metacognitive knowledge is not only related to practice and performance, but also to learning as it reflects the ability to achieve controlled and reflective learning. In a similar way, when a student observes a piano teacher playing a musical passage which was previously played by the student, brain regions related to the motor sensory system of the student are also likely to be activated, functioning as a mirror neurons system effect. In a similar way, when the teacher observes their students playing, brain regions related to movements of the teacher might also be activated as a mirror neurons system effect, which might also occur when modelling is used in piano learning and teaching. What happens inside individuals, intrapersonal feedback, involves not only auditory, visual, and proprioceptive feedback, but also can include conscious-awareness of their playing, self-regulation skills, and metacognitive knowledge.

Intrapersonal feedback in piano playing is exemplified in Figure 3.1, which shows the whole body of a pianist during a performance. Although all the senses encompass vision, audition, touch, smell, taste, proprioception, including kinaesthetic, and tactile, and vestibular feedback, those senses that are associated with piano-related research studies are outlined in Figure 3.1, as they are considered equally important for the purposes of piano learning and teaching.

Figure 3.1 Model of intrapersonal feedback in piano playing

Key: Retrieved from [http://www.musictimes.com/articles/3258/20140107/lang-who-metallicas-grammys-performing-partner.htm in 01/06/2015](http://www.musictimes.com/articles/3258/20140107/lang-who-metallicas-grammys-performing-partner.htm)

Apart from sensory feedback, self-regulatory learning skills and metacognitive knowledge, there is another sense that might not be so apparent: this is the sense of self as defined by Damasio (2000). The sense of self can be conscious or unconscious for the pianist. It is also related to internal states of the body such as 'state of feeling', which is inside the body of the pianist, 'state of emotion', which is often shown to others such as the audience, and 'state of feeling made conscious' (Damasio, 2000, p.

37). However, according to Damasio (2000, p. 36) ‘the full and lasting impact of feelings requires consciousness, because only along with the advent of a sense of self do feelings become known to the individual having them’. Damasio also stated that there might be an ‘integration of sensory representations across modalities—say, vision *and* auditory, or vision *and* touch’ which ‘may well depend on timing mechanisms that coordinate activity across large regions of the brain’ (Damasio, 2000, p. 160).

In these ways, a pianist who is playing a piece expresses themself with emotions, but the feelings that they experience might be conscious or unconscious. Another aspect of the model of intrapersonal feedback which needs to be taken into account in piano learning and playing is ‘the autobiographical self’ that draws on recent or remote memorized history and social and emotional experiences which are made conscious (Damasio, 2000, p. 210). Thus, the autobiographical self might include the entire autobiography of the pianist as an individual. The sense of self might also be inherent or intrinsic for a pianist during their piano performance.

In conclusion, this section of the literature review has demonstrated that intrapersonal feedback in piano learning and playing involves auditory, visual, proprioceptive and vestibular feedback, conscious-awareness, self-regulatory skills, metacognitive knowledge, and a sense of self, which includes states of feeling, emotion and conscious feeling, autobiographical self and memories.

3.11 Summary

This chapter has provided an overview of recent research studies on intrapersonal feedback in piano learning and playing. Intrapersonal feedback in piano-related studies has received an increased focus in the published literature over the last two decades. Several studies have explored sensory feedback by examining the role of auditory, visual and proprioceptive feedback in piano sight-reading, learning, and playing, (Banton, 1995; Finney & Palmer, 2003; Repp, 1999), and in piano ensemble synchronization (Bishop & Goebl, 2015; Goebl & Palmer, 2009; Kawase, 2014). Research shows that auditory feedback is crucial in learning and memorizing a new piece (Finney & Palmer, 2003). However, self-auditory feedback does not play a crucial role in accomplished piano performances by expert pianists (Finney & Palmer, 2003; Repp, 1999; Wöllner & Williamon, 2007), or in piano sight-reading (Banton, 1995).

Perturbations of auditory feedback, such as timing delay, pitch alteration and loudness, disturb solo piano performances (Finney, 1997; Furuya & Soechting, 2010) by altering proprioceptive feedback (Furuya & Soechting, 2010). Removal of auditory feedback of the partner affects synchronization between players in piano ensembles (Bishop & Goebl, 2015; Goebl & Palmer, 2009). Visual feedback of keyboard and hand movements is crucial in piano sight-reading, particularly for non-expert piano sight readers (Banton, 1995). Proprioceptive feedback in combination with auditory feedback such as playing and listening seems to be more beneficial in piano learning and recalling pieces than in learning with solely auditory feedback such as through listening only because auditory-motor associations enhance learning (Bishop & Goebl, 2015; Brown & Palmer, 2012; Halwani et al., 2011; Lahav et al., 2007; Moore et al., 2016). Perturbations of proprioceptive feedback in terms of tapping instead of playing interfere with piano performances more than perturbations of visual and auditory feedback (Wöllner & Williamon, 2007). Proprioceptive feedback was shown to be different across pianists when playing the same piece in different tempi (Goebl & Palmer, 2008).

Intrapersonal feedback seems to involve not only sensory forms of feedback, such as auditory, visual and proprioceptive feedback, but also aspects of conscious-awareness, self-regulation skills, metacognitive knowledge, and sense of self. Conscious-awareness in piano playing may be related to intrapersonal feedback from proprioceptive sources (Acitores, 2011), and it involves knowledge of the experience of the individual and the environment (Damasio, 2012) even if individuals become aware of actions after performing a piece as a post-hoc phenomenon (Jeannerod, 2006). Advanced level pianists may have the potential to develop self-regulated skills when they encounter a fertile learning environment where specific performance goals are defined, where pianists can self-assess their performances, and they can self-monitor their learning (Nielsen, 2001). Self-regulatory skills may also influence the metacognitive knowledge of pianists about themselves and their performances, since they reflect critically on their learning (Schraw & Dennison, 1994). Finally, the sense of self also contributes to intrapersonal feedback in piano learning and playing since the feelings and their integration with sensory feedback have an impact on learning (Damasio, 2000). In Chapter 4, the literature on interpersonal feedback in instrumental and vocal learning and teaching is reviewed.

4 Literature review: interpersonal feedback

4.1 Introduction

Chapter 4, the last of three literature review chapters, focuses on reviewing recent studies of interpersonal feedback in the Western classical music context. Interpersonal feedback can take two forms: between individuals, and (virtually) between individuals and technology. Interpersonal feedback occurs between teacher and student in one-to-one instrumental lessons through verbal and non-verbal interactions, as well as between students and their peers in a small group context. Interpersonal feedback can also take place between technology and individuals via video recordings, audio recordings, visual feedback through computer screens, digital pianos, software programs, and so forth. This chapter presents a detailed literature review of interpersonal feedback between teacher and student in different learning contexts. The chapter will address one-to-one instrumental and vocal lessons in the Western classical music context, focusing particularly on one-to-one piano lessons. The learning contexts include HE and non-HE contexts where most of the literature in one-to-one piano learning was researched, and individual and small group piano lessons. The musical performance parameters usually associated with piano-related studies are also discussed. A review of interpersonal feedback between technology and individuals is also presented which focuses on the broader use of technology in music education, and on the specific use of technology in terms of, for instance, RTVF in instrumental and vocal learning.

4.2 One-to-one instrumental learning and teaching

There has been increasing interest in undertaking research on one-to-one instrumental and vocal learning in the context of Western classical music over the last two decades (see Creech & Gaunt, 2012, for an overview). In their overview, Creech and Gaunt reviewed several previous studies in the field and reported the benefits and disadvantages of one-to-one tuition in the instrumental learning and teaching environment. Strengths of one-to-one learning included 'personalized learning, continuity achieved through a sustained relationship over time, and the intensity of close personal interaction' (Creech & Gaunt, 2012, pp. 695-696). Problematic issues revealed unprepared teachers who were nonetheless expert musicians. This finding underpinned the call for 'systematic professional development' (Creech & Gaunt, 2012, pp. 695-696).

The master-apprenticeship model as a type of teacher-student relationship in instrumental tuition has been discussed by many researchers (e.g. Hallam, 1998; Jørgensen, 2000). The tradition of this relationship has been predominant in one-to-one instrumental learning and teaching. This model is 'where the master usually is looked at as a role model and a source of identification for the student, and where the dominating mode of student learning is imitation' (Jørgensen, 2000, p. 68). Based on a previous study of adult learning and teaching in nine different educational contexts (Pratt, 1992), Hallam (1998, pp. 232-241) discussed five types of teacher-student relationships in a musical context. The first type of relationship, engineering, 'is concerned with the delivery of content and is teacher dominated'. The second, the apprenticeship model, 'is concerned with the development of knowledge and ways of being'. The third type of relationship described by Hallam, developmental, 'stresses facilitating the development of intellect and personal autonomy'. The fourth, a nurturing conception, 'sees the learner and their self-concept as central'. Finally, in the fifth conception of student-teacher relationship called social reform, 'sees teaching as developing an ideal based on a particular set of beliefs'.

The master-apprenticeship model in traditional Western instrumental and vocal learning and teaching is characterized by the use of musical notation. The role of musical notation or the printed music score in instrumental learning and teaching was investigated in two studies (Bautista, Echeverría, Pozo, & Brizuela, 2009; Hultberg, 2002), with a theory of instrumental teaching—based on the roles of musicians and the functions of the printed score as mediators in musical meaning—proposed by

Hultberg (2002). Hultberg identified two main approaches when asking musicians to perform and then comment on printed scores of one well-known and three unknown short pieces. These approaches were reproductive and exploratory. In the reproductive approach, the music score was taken as a complete source that contains all aspects related to the musical meaning of the piece regarding ‘the editor’s special interpretation of the composer’s intention’ in how to interpret the pieces (Hultberg, 2002, p. 189). In the exploratory approach, however, the music score was taken as an incomplete source where musicians decided ‘to disregard the editors’ instructions, and to give priority to their personal judgement instead’ (Hultberg, 2002, p. 192).

In the study by Bautista et al. (2009) conducted in Spain, two hundred and fifteen piano students of both sexes and different personal backgrounds were divided into three age groups 12-14, 17-20, and 22 years and above, which were also related to their level of expertise. These participants were given an ‘open-ended task’ which asked them to imagine they were teachers of an average student at the same level as their own. The piano student participants were asked to identify ‘the five most important things’ (Bautista et al., 2009, p. 199) which their average student should learn from a piano piece selected from a list, which included pieces the participants were already practising. The participants had access to their selected musical score during this open-ended task. Findings showed that participant perspectives varied not only according to their level of expertise and age, but also in musical aspects. For example, participants at a lower level of expertise ‘exclusively focused on the acquisition of the scores’ basic components (i.e., graphic notations)’, while in the intermediate group, ‘psychomotor dimensions and syntactic processing of musical scores were the most important foci of attention’. In contrast, for the more expert group, ‘analytic and artistic processing of musical scores’ were referenced (Bautista et al., 2009, p. 196). These research outcomes are in line with findings by Hultberg (2002), where participants adopted one of two approaches to scores, regarding them either as a complete source by taking the graphical representation as the finished performance, or as a source to be explored by seeing beyond the graphical representations.

Facing and trying to cope with several positive and problematic issues in individual instrumental tuition, Creech and Gaunt (2012, p. 701) argue that ‘the one-to-one encounter is a forum where technology acts as a medium of transformative change’. This transformative change through technology ranges from the use of information and communications technology (ICT), to the application of assistive software programmes for vocal and instrumental learning and teaching. Following this idea that the use of technology might impact on one-to-one instrumental learning and teaching, Creech and Gaunt (2012) predict the need for a shift from the master-apprentice and reproductive model towards a transformative change model in the one-to-one instrumental learning and teaching process by focusing ‘on student reflection, autonomy [and] motivated, self-directed learning’ (Creech & Gaunt, 2012, p. 703). Among several suggested approaches in the transformative change model is the use of technology in instrumental lessons, such as in the form of ‘video recording performances or practising sessions and using these to stimulate reflection and collaborative critical evaluation’ (Creech & Gaunt, 2012, p. 704). While some research has highlighted the supportive use of technology in one-to-one instrumental learning, other research has investigated the role of teacher feedback.

4.3 Interpersonal feedback in instrumental and vocal lessons: an overview

Interpersonal feedback has been customarily used by teachers to inform students about what can be improved in their performance, or in their technical or interpretative playing. Feedback has been frequently examined in studies where researchers have sought to investigate the interaction between teacher and student in instrumental lessons. Observation of teacher and student behaviour has shown that the provision of feedback in instrumental lessons appears to be linked to the interpersonal relationship between teacher and student (e.g. Burwell, 2010), and to the accomplishment of both explicit and implicit goals.

Feedback has been investigated as one of the core components of teacher behaviour, and is also related to student behaviour. In several studies regarding music learning and teaching ‘verbal feedback is the most widely studied component of teacher behaviour’ (Duke & Henninger, 2002, p. 75), which has mostly been measured by ‘experimental and descriptive research’ (Duke, 1999). Most studies that have investigated teaching effectiveness, ‘reinforcement’, teacher-student interaction or sequential patterns of instruction in piano lessons have observed teacher and student behaviours as their methodology.

Various terminologies have been used in music research regarding teacher feedback. ‘Reinforcement’ is one such term commonly related to verbal feedback and has also been found in the literature of instrumental music learning and teaching, as well as in motor control and learning studies. The term ‘reinforcement’ is rooted in psychology, particularly in the work of the ‘Behaviourist School’ (Annett, 1969; Baum, 2005; Garrett, 2009; O'Donohue & Kitchener, 1999) and so will not be used in this thesis as an equivalent to ‘feedback’ (see Chapter 2, for concept of feedback). Positive feedback can appear in the literature as verbal approval, or simply approval, or as positive reinforcement. In the same way, negative feedback, depending on the source, can appear in literature as verbal disapproval, or simply disapproval, corrective feedback, or negative reinforcement. In addition, teacher feedback can be offered in terms of Knowledge of Results (KR), when the teacher gives meaningful information about the outcome of a student performance in terms of a defined goal, and Knowledge of Performance (KP), such as when the teacher gives meaningful information about the movement used by the student during performance (Magill, 1989; Schmidt & Lee, 2011; Welch, 1983, 1985a, 1985b). According to Duke and Henninger (2002, p. 77), ‘although these terms have different meanings, they are generally applied to the same type of verbalization’.

Effective teaching in music has been evaluated in several studies (see Duke, 1999, for an overview) through the investigation of teacher and student behaviours in order to understand the ‘effects of teaching on student learning’ (Duke & Buckner, 2009, p. 18).

According to Duke, ‘every teaching-learning episode includes multiple instructional goals many of which involve the presence (or absence) of changes in student behaviour’ (Duke & Buckner, 2009, p. 18). Teachers provide meaningful feedback based on performance goals they set up; they then expect their students to accomplish these goals through their performance behaviour changes (Duke & Buckner, 2009). Teacher feedback which defines performance goals is thus an important feature of teacher behaviour, one which enables teachers to assess teaching effectiveness in terms of whether the defined goals have been accomplished. Furthermore, the immediacy with which feedback regarding student performance outcomes is delivered by the teacher is crucial for effective learning and teaching (Duke & Buckner, 2009).

The importance of teacher feedback in instrumental music lessons appears to be clear from the investigations reported in several studies. Feedback has been researched to a greater extent in terms of its quantity rather than in terms of its quality within research studies on effective instrumental and vocal teaching and learning (see Duke, 1999, for an overview). Quantity of feedback, in terms of general positive and/or negative feedback, has received more attention in music research, and has mostly been measured in terms of the duration and frequency of verbal feedback. In addition, effective music teaching has been measured ‘in specificity from frequency counts of verbal feedback to global evaluations of overall effectiveness’ (Duke, 1999, p. 1). In contrast, quality of feedback in terms of types of specific feedback linked to clear lesson focus and well-defined performance goals has been less researched. There is an apparent need, therefore, to explore the nature of feedback in instrumental learning and teaching, particularly in the HE context, not only in terms of types of feedback, both verbal and non-verbal, but also in relation to the musical performance parameters with which feedback is linked, for instance, dynamics, tempo, and articulation.

Interpersonal feedback between teacher and student has been investigated in several studies in one-to-one piano lesson settings (Benson & Fung, 2005; Duke & Buckner, 2009; Kostka, 1984; Siebenaler, 1997; Simones, Schroeder, & Rodger, 2013; Simones, Rodger, & Schroeder, 2015; Speer, 1994). Teacher and student behaviours have been conceptualized in categories in order to understand the components of effective teaching and student achievement. For example, some categories of teacher behaviours have been conceptualized as: feedback (Duke & Buckner, 2009); teacher feedback, in terms of verbal approval or disapproval (Speer, 1994); specific directions, specific approval, general approval, and specific disapproval (Siebenaler, 1997); teacher verbalization (Benson & Fung, 2005; Duke & Buckner, 2009; Simones et al., 2013; Simones et al., 2015); and social (non-academic) and academic approval or disapproval (Kostka, 1984). Examples of student behaviours which were classified in these studies include: student participation (Speer, 1994); verbal response (Benson & Fung, 2005; Siebenaler, 1997; Speer, 1994); student performance (Duke & Buckner, 2009); student verbalization (Duke & Buckner, 2009); and student question, student playing, student singing, and off-task behaviour (Benson & Fung, 2005). The relationship of teacher gestures and communication in piano studios seem to be dependent on student level of expertise (Simones et al., 2013; Simones et al., 2015). In addition, teacher and student behaviours have been evaluated in regard not only to effective teaching, but also in regard to the accomplishment of defined goals by students in piano studio settings (Duke & Buckner, 2009).

The main findings of research studies of piano lessons in non-HE contexts can be summarized in the following seven points. First, effective piano teaching appears to be linked to specific feedback, where the most effective and more experienced teachers are more specific, mainly in the form of negative feedback, than general positive/negative feedback (Siebenaler, 1997). Second, effective piano lessons are likely to be short in terms of student performance episodes, but include active teacher participation with regard to feedback, performance, and verbal instruction (Siebenaler, 1997). Third, giving specific negative feedback appears to be a characteristic of more experienced piano teachers (Speer, 1994). Fourth, piano teachers tend to give feedback for academic purposes more frequently rather than for non-academic purposes to their students (Kostka, 1984). Fifth, while similar teacher behaviours were reported across countries of different cultures, differences were found in relation to the quantity of modelling and verbalization during piano lessons (Benson & Fung, 2005). Sixth, lessons by the most successful teachers tended to be more frequent and shorter in terms of student performance episodes, teacher verbal feedback and teacher performance (Duke & Buckner, 2009). Finally, teacher gestures, such as 'conducting style', 'metaphoric', and 'iconic', seem to support communication in a piano studio setting and differ according to the student level of expertise (Simones et al., 2013; Simones et al., 2015, p.729). The research body drawn upon above is significant in terms of the conceptual framework of this thesis as it provides a synthesis of the nature of feedback in instrumental and vocal learning and teaching, which is an under-investigated field in non-HE, and particularly in HE settings.

Research has shown that interpersonal feedback in a small group setting appears to benefit piano learning and teaching (Daniel, 2003, 2006). According to teachers, small piano group activities were seen to stimulate students to think critically about their own performance, and to improve performance and technical skills. In small piano group activities, students perceived that they were given more feedback, had a faster pace of learning, and learned to be more independent learners through peer comments and self-critical analysis (Daniel, 2003). In such lessons, teachers and students were observed to share responsibilities: teachers provided more feedback and students appeared to take more responsibility for learning (Daniel, 2006). One-to-one piano lessons, though, tended to be dominated by the teacher. This research is significant because it contributes to the current study in terms of the nature of feedback in instrumental learning and teaching, particularly into the context for feedback in a piano studio.

Interpersonal feedback has also been investigated in other-than-piano contexts, for instance, violin (Creech, 2012), recorder (Duke & Henninger, 1998, 2002), and viola, guitar and singing (Karlsson & Juslin, 2008). Research into individual instrumental lessons other than for piano have demonstrated that specific feedback, either positive or negative, tended to provide students with meaningful information which can contribute to student autonomy (Creech, 2012). In line with Creech (2012), the type of teacher feedback, such as positive and negative, did not appear to interfere with student attitudes in lessons, or influence learning efficacy according to the students themselves (Duke & Henninger, 1998), or to external observers, such as future music teachers (Duke & Henninger, 1998, 2002). However, general feedback and verbal instruction appear to be the most frequent feedback strategies given by teachers in lessons when compared to other types, such as modelling and use of metaphors (Karlsson & Juslin, 2008).

Instrumental teachers give information about student performances through feedback. Two types of interpersonal feedback which are commonly reported in instrumental learning and teaching are: verbal feedback, when the teacher verbalizes the outcome of student performance, and non-verbal feedback, when teacher does not use verbalization to inform the student about their performance but relies instead on other means. Verbal feedback not only includes positive and negative comments, but also specific or descriptive statements and non-specific or general and non-descriptive statements. General positive or negative feedback is seen to be related to the performance outcome through comments. Some examples of verbal feedback during HE level instrumental playing are in the form of general positive or negative comments such as “that's good” “that’s better […] that’s great” (Burwell, 2010, pp. 196-197) or “No” (Burwell, 2010, Appendix D) as well as ambiguous general feedback such as “that was interesting!” (Burwell, 2010, Appendix D).

More specific feedback, in the form of positive or negative comments, give detailed information about aspects of performance such as “[i]f you could make that shape seamless and then this *con duolo*, I think you can really lay it on thicker there” and “[t]his, partly because you moved your feet in the middle, you, you kind of lost the feeling of calm, there was a bit too much waggling around which, urm, destroyed the line for me” (Burwell,2010, p. 166, original emphasis). Similarly, examples of non-verbal feedback during or following instrumental playing can take various forms such as teacher playing (Bryant, 2004; Burwell, 2010). This is when the teacher plays the piece, demonstrating to the student either how the piece is currently being played or how it should be played. Other ways of offering non-verbal feedback are reported to include: eye contact, when the teacher uses eye contact after a student performance; making gestures, when the teacher gestures with their head such as nodding or shaking, hand movements, such as tapping, snapping the fingers, conducting, or even moves the foot, when tapping the beats; and other non-verbal feedback such as smiling and laughing (Burwell, 2010). The provision of feedback is crucial to learning and it contributes to effective teaching. Although feedback in instrumental learning and teaching has been investigated in piano and other instrument settings, the nature of feedback in an HE piano studio context remains under-researched.

4.4 Interpersonal feedback in HE instrumental and vocal learning and teaching

The nature of one-to-one instrumental and vocal lessons in HE has been investigated in interview studies looking at the perceptions of teachers and students (Burwell, 2010; Carey & Grant, 2015b; Gaunt, 2007, 2009, 2011), and in observational studies (Bryant, 2004; Burwell, 2010; Carey, Bridgstock, Taylor, McWilliam, & Grant, 2013). Teachers and students in HE have seen feedback as an important component of effective teaching and for student performance achievement (Gaunt, 2007, 2009). The use of technology, such as audio or video recording, in instrumental and vocal learning has also been addressed in some studies (Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010), and also in relation to feedback (Burwell, 2010; Gaunt, 2007, 2009; Welch et al., 2005).

One-to-one teacher and student interaction in HE piano learning and teaching was investigated in a study in the UK (Bryant, 2004). This longitudinal study was conducted over a two-year period and used observation and participant reports to investigate the 'influences and effects' of teacher and student interaction in one-to-one piano lessons (Bryant, 2004, p. ii). Five pairs of teachers and students, five students and three teachers, worked on piano pieces by Bartok, Prokofiev, Debussy, Chopin and Shostakovich. Lessons mainly encompassed 'three steps: student performance, teacher's assessment and advice' (Bryant, 2004, p. 236). Findings suggested that student talk was minimal in the observed lessons, but a considerable amount of time was spent on student non-verbal behaviours for playing, encompassing gestures and movements. Eight different musical parameters were categorized in this study: pitch, rhythm, dynamics, tempo, pedal, articulation, interpretation, and technique. Findings from this study suggest that teacher-student relationships and lesson behaviours are: 'asymmetrical, teacher dominated, formulaic, unchanging over time, teacher promoted, student supported, influenced by previous experiences' (Bryant, 2004, pp. 235-236).

One recent study addressed the perceptions of twenty one-to-one instrumental and vocal teachers in a conservatoire in the UK as to their practice, aims, process and context, by using semi-structured interviews (Gaunt, 2007). Findings suggested that although eleven of the twenty teachers highlighted the importance of student independence and autonomy in learning, a discrepancy was found between the aspirations of teachers and the actual processes of teaching. Reported teaching approaches were modelling, discussing aspects of playing, playing along, questioning, working at posture, and giving feedback on performance. Regarding the use of technology in lessons, some teachers agreed that 'making a video or audio recording of a student's performance and asking the student to comment' is another way of providing feedback (Gaunt, 2007, p. 225). Some teachers encouraged students to audio or video record 'their lesson as an aide-mémoire' and 'at particular points in their individual practice' (Gaunt, 2007, p. 227). Of the twenty teachers interviewed, ten commented on their use or otherwise of technology: three teachers 'played back recordings of their students during lessons and used these for collaborative reflection', two teachers 'strongly disliked the effects particularly of video recording', and five teachers 'expressed an interest in using technology more' (Gaunt, 2007, p. 227). However, 'no teachers indicated that they used school audio/video recording equipment as part of their teaching practice in the college' (Gaunt, 2007, p. 226). Reasons given for not using school media facilities were 'logistic difficulties with this within the college' and time constraints, which 'made reviewing recordings relatively ineffective' (Gaunt, 2007, p. 227). Three main findings were evidenced. First, teachers perceived student autonomy as a characteristic of the individual student rather than a feature which could be improved by tuition. Second, teachers wanted students to think independently, but they did not use approaches which offered room for student participation in the learning process. Third, teacher perceptions of their teaching differed from the actual teaching processes which they employed.

Parallel to the study above, perceptions of twenty instrumental and vocal students in the same conservatoire in the UK regarding their experience of one-to-one tuition in terms of frequency and length of lessons were also analysed (Gaunt, 2009). Students reported that some aspects of teaching, such as positive feedback and questioning in relation to musical interpretation, promoted self-confidence and facilitated greater autonomy respectively. However, student verbalization or questioning did not occur when they 'struggled to understand the teaching, or perhaps wanted a different emphasis in the type of feedback being offered' (Gaunt, 2009, p. 193). In other words, students did not communicate that they did not understand the directives or instructions of their teachers, or when teacher feedback was not meaningful for them. The results of this study suggest that anxiety in learning can be lessened by encouraging 'rapport and trust in the communication between students and teachers; objective feedback; empowerment of students through developing intrinsic confidence; and the development of autonomy as a learner' (Gaunt, 2009, p. 199).

The match between student and teacher perceptions in one-to-one instrumental and vocal learning and teaching was also investigated subsequently by Gaunt (2011) in the same conservatoire in the UK as in the two previous studies. In this third study, both teacher and student reported not only the uniqueness, but also the complexity of the one-to-one student-teacher relationship. Findings showed that teachers labelled relationships as 'friendship', 'parent-child relations' a 'mixture of the two', and 'doctor-patient dynamics' (Gaunt, 2011, p. 165). At the same time, students seemed to perceive one-to-one tuition as functioning for their own development as musicians and technical skills (Gaunt, 2011, p. 166). Findings of this study showed 'a number of areas of potential tension within the relationship' (Gaunt, 2011, p. 174) in one-to-one instrumental and vocal studio as follows:

> between individual autonomy and dependence in student and teacher; between power invested largely in the teacher and shared power; between trust, support and immersion necessary to the work and the need to stand back and evaluate critically; and between focusing on musical issues alone and attending holistically to a student's overall development (Gaunt, 2011, p. 174).

The interaction between teacher and student was investigated by Burwell (2010) in a study of instrumental learning and teaching in HE. Two single individual clarinet lessons given by an expert teacher to two undergraduate students with different ability levels were observed and video-recorded. All three participants were interviewed in order to collect participant perspectives of their videoed lessons (Burwell, 2010, p. 3). In this study, lesson behaviour was categorized as spatial, performance or verbal. Spatial behaviour included the use of physical space by each participant in relation to themselves, such as body movement, to the other participant, and to objects in the room (Burwell, 2010, p. 151). Performance behaviour was divided into four categories: rehearsal, such as reading the score or performing; preparation, such as silent moments which preceded playing; practice, such as difficulty with technical issues; and exercise, such as warming up or playing scales (Burwell, 2010, p. 153). Teacher verbal behaviour was placed into four categories: information on student performance or musical notation; elicitation or posing questions to the student; coaching such as giving direction or guidance; and feedback such as observations and evaluations after student performance (Burwell, 2010, p. 166). Although student verbal behaviour was minimal, it was classified into three categories: information, such as providing verbal responses; elicitation, in terms of asking questions; and back-channelling (Burwell, 2010, pp.173-175). Back-channelling was a student verbal behaviour in terms of concise and monosyllabic comments, for instance "Mmm", "Umm", ''Yeah'', "Right" and "Okay" (Burwell, 2010, p. 171). Findings indicated that: first, non-verbal behaviour 'provided some access to the affective states of participants' (Burwell, 2010, p. 242); second, 'coaching and feedback in particular have been found to be closely related to the students' performance activity' (Burwell, 2010, p. 242); and third, 'lesson activity is multidimensional and collaborative, constructed by teacher and student together' (Burwell, 2010, p. 243). Based on the 'contrast between the two lessons', this study 'suggests a circular relationship between procedure and product, lesson behaviour and student learning, with one always implicated in the other' (Burwell, 2010, p. 244). In conclusion, this study demonstrated that instrumental learning and teaching might depend on the interactions between the teacher and student and can vary according to teacher and student behaviours.

Teacher and student perceptions in one-to-one HE instrumental and vocal learning and teaching were investigated in one study in Australia. This study was conducted through holding interviews with teachers and focus groups with students (Carey & Grant, 2015b). Findings revealed that modelling, in terms of the teacher modelling a correct way of playing and the student imitating it, dominates in teacher-led lessons. This pedagogical style can make students dependent on modelling, even though some of the students complained about it, wanting instead to acquire more autonomy in lessons. In general, perspectives on one-to-one pedagogy in instrumental and vocal lessons showed that:

> Both teacher and student participants also encountered some challenges with the one-to-one model, including the complexities of negotiating an appropriate teacher-student relationship; the difficulties of striking the right balance between teacher-led and student-led learning; and the necessity for one or both parties to adapt to the personality and teaching/learning style of the other (Carey & Grant, 2015b, p. 17).

Efficacy of the practice of one-to-one HE instrumental and vocal learning and teaching has also been investigated through video observation (Carey et al., 2013). A quantitative analysis approach was conducted which revealed two types of pedagogical approaches: transformative and transferring pedagogies. The transformative pedagogical approach 'places emphasis on a depth of student understanding and ownership […] collaborative, explorative, scaffolded, meaningful and contextualising qualities' (Carey et al., 2013, p. 361). The transfer pedagogical approach 'is characterised by instruction, scaffolding that promotes mimicry, less flexibility, orientation towards assessment and decontextualized learning' (Carey et al., 2013, p. 362). Findings of this study suggest that in order to adopt a 'transformative pedagogy', four aspects need to be considered: 'purpose of practice', 'pedagogical agility', 'approach to diagnosis', and 'approach to meaning-making' (Carey et al., 2013, p. 366). This research is significant in terms of its findings since it offers an alternative way to change the traditional pedagogical approach and to enhance HE instrumental and vocal learning and teaching. This will also be drawn upon in the current study into the application of technology-mediated feedback in a piano studio.

Research studies in instrumental and vocal learning and teaching in HE have demonstrated that teachers expect their students to be independent and have a degree of autonomy over their learning (Carey & Grant, 2015b; Gaunt, 2007), while students expect their teachers to use teaching strategies to develop their autonomy and independence as learners (Carey & Grant, 2015b; Gaunt, 2009). Since teachers generally dominate one-to-one tuition (Bryant, 2004), modelling seems to be a predominant practice; as a result, students feel dependent on the teacher playing for their learning, and do not appear to develop their autonomy as they had expected (Carey & Grant, 2015b). In instrumental learning and teaching, there is a circular interaction between teacher and student (Burwell, 2010). Teacher behaviour is likely to feed student behaviour, and vice versa. Although the use of technology in instrumental and vocal lessons was commented on by teachers, technology was not mentioned by students (Gaunt, 2007, 2009). Students, rather than teachers, appeared to be more aware of the quality of feedback and instruction provided by teachers (Gaunt, 2007, 2009). In conclusion, there is evidence to suggest that instrumental learning and teaching are dependent on the interactions between the student and teacher and that these interactions are also likely to vary according to student and teacher biography (Burwell, 2010).

4.5 Musical performance parameters in piano-related studies

In piano learning and teaching, feedback is customarily provided by teachers in order to inform students about what can be improved in their playing for particular musical performance parameters such as articulation, dynamics, tempo, or pedalling (e.g. Bryant, 2004). Several studies have investigated musical performance parameters for different purposes and foci. Although these studies considered musical performance parameters, various research purposes were found, including: analysis of musical performances for solely one parameter such as articulation, fingering, or touch (e.g. Bernays & Traube, 2014; Clarke, Parncutt, Raekallio, & Sloboda, 1997; Palmer, 1989); examining relationships between several parameters such as musical structure and gesture, dynamics and timing, emotional expression and articulation, tempo, and dynamics (e.g. Juslin, 1997; MacRitchie, Buck, & Bailey, 2013; Repp, 1994); understanding the learning process of student or expert pianist performances (e.g. Chaffin & Imreh, 2002; Miklaszewski, 1989); and investigating the criteria used when assessing live musical performances or recordings of those performances by adjudicators (Thompson & Williamon, 2003; Thompson, Diamond, & Balkwill, 1998). In addition, several studies have analysed technology-generated data and related them, for example, to particular musical performance parameters such as dynamics and timing (Bresin & Battel, 2000; Keithley, 2004; Palmer, 1989; Repp, 1996). The nineteen most reported musical performance parameters are discussed below because they have been shown to be related to feedback in piano learning and teaching when student performance is being improved in a lesson (see Table 4.1).

Music structure has been examined in several studies, in combination with other musical performance parameters in piano learning and performance, such as bodily gestures (MacRitchie et al., 2013), attention and memory (Williamon, Valentine, & Valentine, 2002), melodic and rhythmic accents (Pfordresher, 2003), and melody leads or voicing, and articulation (Palmer, 1996). Findings of these studies evidenced whether student or expert pianists can convey the music structure of a piano piece to listeners through the relationships the pianists have made between music structure and other musical performance parameters of their performances.

The relationship between *dynamics* and *timing* has been investigated in research studies in analyses of piano performances (Repp, 1996a). The dynamic balance between hands, and dynamic contour in performances of HE level piano students were investigated with pianists when playing Schumann *Träumerei* on a Yamaha Disklavier. The analyses of piano performances were conducted through hammer velocity measures generated by MIDI data. Findings showed that levels of dynamics were higher for the right hand than for the left following the pitch of the melody, and did not seem to vary across piano students for dynamic levels, except for timing (Repp, 1996). Although two out of ten pianists were left-handed, right/left-handedness was not considered to have affected the results. A higher dynamic level for the right hand was probably related to 'the pianist's intention to emphasize the principal melody over the other voices' (Repp, 1996, p. 646), something which was due to the fact that 'melody was usually played by the right hand' (Repp, 1996, p. 642). Repp (1994) also examined the relationship between *tempo* and *pedalling* by asking pianists to play the same piece by Schumann in three different tempi. The analysis of MIDI data of these piano performances was conducted so that '[t]he timing of pedal depressions and releases was measured relative to key depressions and releases' (Repp, 1994, p. 211). Overall, findings showed that pedal use frequency seemed to increase alongside tempo. However, pedalling frequency also seemed to vary according to the level of expertise of the pianists.

Articulation has been investigated in several studies by analysing recordings of piano performances through MIDI parameters such as inter-onset-interval (IOI), key overlap time (KOT), and key detached time (KDT) (Bresin & Battel, 2000; Palmer, 1989). One study looked at articulation for chord asynchrony and for note overlaps, plus tempo deviations of *rubato* in piano performances (Palmer, 1989). The relationship between the intended performance of the pianist and their musical performance was examined in two experiments when pianist performances were analysed through MIDI data for three aspects: chord asynchrony, rubato, and note overlap. In the first experiment, pianists received instructions to play two versions of a piano piece: musically, and without emotional expression. In the second experiment, pianists were asked to write their intentions on a music score, and these were compared to their performances through MIDI data. Findings showed that performances without emotional expression were poorer in all three aspects (chord asynchrony, rubato, and note overlap), and that more skilled pianists performed with a greater palette of these aspects than students did. Pianist performances showed asynchrony between the melody lead in the chord and the other simultaneous notes in chords, rubato at the end of the musical phrases, and note overlaps for adjacent notes (Palmer, 1989).

Another study examined *articulation* for legato, staccato, and repeated notes in piano performances by different pianists playing an excerpt of a classical piece under nine different expressive conditions, including an optimal or natural performance version (Bresin & Battel, 2000). The piano performances were played on a Yamaha Disklavier connected to a computer which recorded MIDI data. MIDI data were used to analyse the right hand of the piano performances through the analysis of IOI, KOT, KDT, and duration (DR). Findings across pianists suggested that there was 'a strategy to lengthen short notes and to shorten long notes in legato articulation', the degree of staccato articulation varied according to the nine different instructional adjectives, and the articulation for repeated notes seemed to be 'in the range of a mezzo-staccato articulation' (Bresin & Battel, 2000, p. 113).

Touch was analysed alongside three other musical parameters, namely articulation, dynamics and pedalling, in order to investigate individuality in performances by pianists playing four short pieces under five different intentions: bright, dark, dry, round, and velvety (Bernays & Traube, 2014). The four pianists showed significant differences across their individual performances for musical parameters through MIDI measurements which gauged the extent to which the pianists successfully conveyed timbre nuances according to each intention. However, similarities across pianists performing under different intentions were found by relating timbre and emotions, and other musical performance parameters. It was found that ‘velvety and dark timbres may thus be related to sad or tender emotions (low intensity, legato articulation), while a dry timbre may reflect happiness (high intensity, staccato articulation)’ (Bernays & Traube, 2014, p. 15).

Several studies have investigated *fingering*, either through observing pianists playing their instrument (Clarke et al., 1997), or by examining intended and performed fingerings and interactions between right hand and left hand (Parncutt, Sloboda, & Clarke, 1999). In the first study (Clarke et al., 1997), fingering was examined by interviewing pianists. The study demonstrated relationships between fingering and five aspects: task demand, contemporary music, physical factors, interpretation, and knowledge of practice (Clarke et al., 1997). In the second study (Parncutt et al., 1999), intended and performed fingering were compared when pianists were sight reading and playing two studies by Czerny. This study demonstrated that pianists tend to focus much more attention on right hand fingering than on the left by following intended fingering when playing with both hands. Pianists also seemed to stretch adjacent fingers more on the right hand than on the left hand (Parncutt et al., 1999).

Another study analysed *articulation, tempo, dynamics, pedal use,* and *voicing* in order to investigate the communication of four basic emotions: happiness, sadness, anger and tenderness, at different levels of piano performances (Keithley, 2004). The measurements of musical performance parameters of five piano performances were compared with ratings by listener judgements of piano performances. Findings showed that there were relationships between musical performance parameters and emotion. For example, significant use of the damper/sustain pedal was related to sadness, and tenderness, while less frequent use of sustain pedalling was related to happiness. Similarly, dynamic balance favouring the melody rather than the accompaniment was related to sadness and tenderness while dynamic balance favouring the accompaniment was related to anger. Finally, articulation for chord asynchrony was found to be related to perceptions of anger and tenderness (Keithley, 2004).

The communication of *emotional expressions* in performances was investigated in several studies (Gabrielsson & Juslin, 1996; Juslin, 1997). In one study, three instrumental and vocal teachers in HE received the instruction to play four melodies with the seven prescribed emotions: happy, sad, angry, fearful, tender, solemn, and no expression. The participants were also invited to produce an optimal performance where variations to musical performance parameters such as 'tempo, timing, dynamics, articulation, phrasing, vibrato, attack, and timbre' were permitted, although deviations in the pitches in the melody were to be kept (Gabrielsson & Juslin, 1996, p. 72). Different emotional expressions seemed to be related to different qualities of particular musical performance parameters such as legato or staccato articulation, and louder or softer for dynamics. For example, happiness was communicated in terms of 'fast tempo, […] moderate to loud sound level, [and] mostly airy articulation' while sadness was expressed by using 'slow tempo, […] low or moderate sound level, [and] legato articulation' (Gabrielsson & Juslin, 1996, p. 82).

In another study, Juslin (1997) investigated whether an emotion intended by performers was also communicated to listeners through looking at the musical performance parameters related to each type of emotion. The analysis of musical performances revealed prospective relationships between emotional expression and particular characteristics for the musical performance parameters, such as articulation, tempo and dynamics. For example, the communication of sadness was performed softly, in legato style, and in a slow tempo, while the communication of happiness involved playing loudly, in a staccato style, and in a fast tempo (Juslin, 1997, p. 412). These findings are in line with the previous study on emotional expression (Gabrielsson & Juslin, 1996, p. 82). In addition, findings across planned and perceived emotions seemed to be consistent, as listeners were able to decode the intended emotion within the musical performances, which was planned by the performer; this was independent of any musical training among the listeners (Juslin, 1997).

Rubato was investigated in experiments which involved perceiving and imitating the rubato or assessing rubato in musical performances (e.g. Clarke & Baker-Short, 1987).

Clarke and Baker-Short (1987) examined the accuracy of piano players who received an instruction to listen to and imitate four music excerpts, each with four different variations of pitch and timing. Findings suggested that 'performers are able to reproduce complex timing patterns that are played to them' when the musical context sufficiently supports the pattern of rubato (Clarke & Baker-Short, 1987, p. 71).

Alongside these previous musical performance parameters, the use of *metaphor* to improve student performance has also been reported in instrumental and vocal learning and teaching studies; this has resulted in controversial opinions across authors (Davidson, 1989; Persson, 1996; Woody, 2002). In one study, Woody (2002) gave instructions to instrument teachers to describe which metaphors they would use in order to improve the performance of students. Three types of metaphors were found: mood, where emotions and feelings are conveyed; context-free motion, where the movement is described, but not the object; and contextual motion, where 'an object in motion is specified', for instance an animal or a mechanical form of movement (Woody, 2002, p. 220). Davidson (1989) stated that metaphor use can support modelling, as it 'creates an affective state within which the performer can attempt to match the model' (Davidson, 1989, p. 95). However, Persson (1996), when observing a performer teacher with no formal teaching training giving one-to-one lessons in a piano studio, reported that metaphor use seemed to confuse students.

Musical performance parameters were also reported in studies which addressed the learning process of a new piece by a piano student (Miklaszewski, 1989), or by an expert pianist (Chaffin & Imreh, 2002). In an early study, four sessions of practising a Debussy piece by a conservatoire piano student were videotaped prior to a lesson with their piano teacher. The student also made comments whilst watching the videoed piano practice, and these comments were audio recorded. Particular musical performance parameters emerged from analyses of both data sets when focusing on technically difficult passages: technique, tempo, and music structure according to the videoed practice; and fingering and expression, according to student comments (Miklaszewski, 1989).

In a year-long study, Chaffin and Imreh (2002) investigated the piano practice of a piece by Bach by an expert pianist during the learning process up until memorisation. Decisions by the pianist whilst practising shed light on a hierarchical order and interrelated dimensions of musical parameters on five levels. The first level, namely basic, involved fingering, technique, and familiar patterns such as scales, or arpeggios. The second level, interpretative, encompassed phrasing, dynamics, tempo, and pedalling. The third level, performance, combined the basic and interpretative levels. The fourth and fifth levels encompassed expressive and music structure, respectively. These two studies (Chaffin & Imreh, 2002; Miklaszewski, 1989) showed that within the learning process of a new piano piece by an undergraduate student or an expert pianist, musical performance parameters are involved in practising sessions whether verbalized by learners or observed by researchers.

Musical performance parameters are also embedded in the criteria used by adjudicators when assessing musical performances (Thompson & Williamon, 2003; Thompson et al., 1998). In one study, five piano adjudicators were asked to evaluate six anonymised commercial recordings of an etude by Chopin (Thompson et al., 1998). Fifteen musical performance parameters overall were used to evaluate the recordings of piano performances. These were: tempo, climax, form, rubato, pedal, phrasing, right hand, overall, ending, articulation, control, rhythm, dynamics, balance, and musical structure. Findings suggested that those assessments that gave the highest marks seemed to have focused mainly on phrasing and on right hand expression, rather than on tempo, for example (Thompson et al., 1998).

In another study, Thompson and Williamon (2003) asked three adjudicators, including a pianist, to assess different solo musical performances each on a different instrument. These included performances by piano students through video recordings, and were assessed according to a set of fourteen categories. These categories included musical performance parameters such as overall quality, technique, rhythmic accuracy, touch, music structure, style, interpretation, and emotional expression. Findings suggest the assessments across adjudicators did not converge, indicating the individual differences between them (Thompson & Williamon, 2003). This shows that while musical performance parameters have been used as criteria to evaluate excellence in musical performance by different adjudicators, they have also been related to feedback in piano learning and teaching contexts.

Analyses of musical performances have been conducted through *technology-generated MIDI data* which seemed to have a relationship with certain musical performance parameters such as timing, dynamics, articulation, and pedalling (e.g. Bernays & Traube, 2014; Bresin & Battel, 2000; Palmer, 1989, 1996; Repp, 1994, 1996). This musical performance analysis was possible because of the technology-generated data derived from the application of MIDI technology to computer-controlled pianos, for example computer-monitored acoustic pianos such as the Yamaha Disklavier, digital grand pianos such as the Bösendorfer CEUS, and digital pianos such as the Yamaha Clavinova. In these studies, MIDI data were used in order to analyse recorded piano performances quantitatively by relating articulation, timing, dynamics or pedalling through analysis to MIDI parameters such as key or hammer velocity number, IOI, KOT, and KDT, variables which reveal data about pianist key and pedal activity (e.g. Bernays & Traube, 2014; Bresin & Battel, 2000; Palmer, 1989, 1996; Repp, 1994, 1996). By using these types of technology, piano performances can be analysed through technology-generated data such as MIDI data either for qualitative analysis, for example colour and sizes, or for quantitative analysis, for example IOI, KOT, KDT, and key velocity numbers, and by relating them to selected musical performance parameters.

Table 4.1 shows musical performance parameters, in terms of articulation, dynamics, including technology such as MIDI data, which have been reported in some of the recent studies in piano learning and performance as described above.

Table 4.1 Synthesis of musical performance parameters in piano-related studies

Musical performance parameters in piano-related studies																			
Sources	Overall	Music structure	Gestures	Memorization	Accents	Voicing	Articulation	Rhythmic accuracy	Dynamics	Tempo	Touch	Pedalling	Fingering	Emotional expression	Rubato	Technique	Phrasing	Style	MIDI data
Bernays and Traube (2014)							√		√		√								√
Bresin and Umberto Battel (2000)							√												√
Chaffin and Imreh (2002)		√							√	√		√	√	√		√	√		
Clarke and Baker-Shot (1987)										√	√				√				
Clarke et al. (1997)													√						
Gabrielsson and Juslin (1996)							√		√					√					
Juslin (1997)							√		√	√				√					
Keithley (2004)						√	√		√	√		√							
MacRitchie et al. (2013)		√	√																
Miklaszewski (1989)		√								√			√	√		√			
Palmer (1989)							√								√				√
Palmer (1996)		√				√	√												√
Parncutt et al. (1999)													√						
Pfordresher (2013)		√			√														
Repp (1994)										√		√							√
Repp (1996)									√	√									√
Thompson and Williamon (2003)	√	√						√			√			√		√		√	
Thompson et al. (1998)	√	√					√	√	√	√		√			√	√	√		
Williamon et al. (2002)		√		√															

Table 4.1 shows the synthesis of the most reported types of musical performance parameters which have been investigated in research studies where the purposes were to: analyse musical performances by using technology-generated data (e.g. Bernays & Traube, 2014; Clarke et al., 1997; Palmer, 1989); analyse their prospective relationships (e.g. Juslin, 1997; MacRitchie et al., 2013; Repp, 1994); understand the learning process of musical performances (e.g. Chaffin & Imreh, 2002; Miklaszewski, 1989); and evaluate musical performances (e.g. Thompson & Williamon, 2003; Thompson et al., 1998).

These studies give an idea of the most common musical performance parameters that have been reported within the context of piano performance, piano learning and practice process, piano assessment, and performance analysis. This provides insights for the current study in terms of context because there is evidence of relationships between MIDI parameters such as visual metaphors which are generated by technology and musical performance parameters, for instance dynamics, and articulation, which are usually reported in conventional piano studio. A review of the recent studies which applied technology in the context of musical education, music studio and instrumental and vocal learning is discussed below.

4.6 Technology and music education in general

ICT has been revolutionizing the way that individuals deal with the world and their own reality. It is impossible not to acknowledge the increasing and varied use of technology by individuals in the 21st century for entertainment, communication and problem solving. The rapid development of technology for music listening, for example, has been witnessed by individuals like myself: from the long-play LP, cassette K7, compact disc (CD), minidisc (MD), and more recent audio files in waveform and MP3.

An historical overview of the evolution of music technology, from the metronome to software programs such as Audacity, digital audio workstation (DAW), and MIDI, was reported by Himonides (2012). This increasing use of ICT has impacted on music learning and teaching. In the field of music education in mainstream schools, ICT has impacted on learning through the use of Sibelius Avid Technology, Cubase Steinberg, and Audacity (Savage, 2007), while in HE music ICT has affected learning through the use of a Learning Technology Interface (LTI) (King, 2008). In instrumental and vocal learning, ICT has also supported students in learning through GarageBand and Sibelius Avid Technology, through listening to recordings and watching videos of performances, or monitoring their practice through self-recording of their performances (Zhukov, 2013). The impact and influence that the increasing and diverse types of technology have had (e.g. King, 2008; Savage, 2007; Zhukov, 2013) will be reported in this section.

In the context of secondary level school music education, Savage (2007) conducted an investigation into the application of ICT by observing music teaching in eighteen mainstream schools in the UK, and the use of new technologies by artists. Observations suggested that only a small variety of software programmes were used by music teachers. For example, 94% of teachers used Sibelius Avid Technology software for writing a music score, 77% used Cubase Steinberg DAW software for recording, arranging, and playing back, and 22% used Audacity for editing audio files (Savage, 2007, p. 69). One reported advantage of using software in music learning over learning to play acoustic instruments was that pupils showed increased motivation. In contrast, disadvantages appeared to be decreased confidence when performing and less observed peer-to-peer interactions which were substituted for human-computer interaction. Three findings arose from this study: ‘teaching music with ICT is in some senses broadly similar to and in other senses quite different from teaching music without ICT’ (Savage, 2007, p. 72), ‘ICT can legitimately be used to support and extend traditional approaches to music education’ (Savage, 2007, p. 72), and ‘ICT in music education has the potential to transform the nature of the subject itself as well as how it could be taught’ (Savage, 2007, p. 74).

In an HE context, the application of a LTI program in a two-hour session during a drum recording task in a music studio context was examined (King, 2008). Participants were divided into two groups using different supporting materials to complete the task; the control group of paired students used a paper-based manual, and the treatment pairs used the LTI technology. Findings suggested that the LTI drum recording session not only made the learning process more rapid, but that the treatment group also achieved a higher mark than the control group of students (King, 2008). Four types of student collaboration were noted. First, 'full' or integral collaboration between students was observed when pairs used the supporting materials, either LTI or manual, to complete the task. The second type, 'isolated', described how one student was observed to have worked alone. The third type, 'relay', was observed when there was a division of collaboration between students towards completing the task with or without the supporting material. The fourth, 'unsupported', type of task completion was noted where students collaborated with each other, but ignored the supporting material (King, 2008, p. 431). There was evidence that 'full' collaboration existed between those pairs of students who used LTI whereas the pairs of students who used the paper manual 'worked independently, showing 'isolated' collaboration, or by relaying information to one another' (King, 2008, pp. 434-435). In conclusion, the study demonstrated that 'LTI appeared to act as a more effective contingent learning tool than the manual because it encouraged 'full' collaboration among the students' (King, 2008, p. 435).

In another recent study in Australia, the role and impact of technology on the learning of instrumental and vocal students was investigated (Zhukov, 2013). The survey involved 189 HE students with intermediate or advanced levels of expertise. Quantitative data analyses showed that the majority of the students were interested in using technology in their learning, with 73% already owning software such as GarageBand and Sibelius, and 78% expressing an interest in technology-assisted instrumental learning (Zhukov, 2013). Some students were reported to have listened to and watched videoed performances available on YouTube for guidance, and half of them reported having made self-recordings (Zhukov, 2013). Findings highlighted the significant role of technology in independent learning outside the one-to-one lesson environment: 'students are recording themselves on a regular basis to monitor their own progress, are comfortable using music software and open to the idea of using technology to monitor their practice' (Zhukov, 2013, p. 78). For teachers, this research emphasized the importance and relevance of being up-to-date with technological innovations in music studios (Zhukov, 2013).

This section has provided evidence of the benefits of technology use in music education when applied in classrooms (Savage, 2007), in HE music production and recording studios (King 2008), and in instrumental or vocal learning (Zhukov, 2013). The major benefits are argued to include a change from a traditional teaching approach to a more transformative form of tuition (Savage, 2007) which can stimulate collaborative learning environments for individuals involved in technology-related activities (King, 2008). Apart from these benefits to learning, it can be argued that since students are already involved with technologies in their personal lives outside academia (Prensky, 2001), a change in teaching approaches to one which embraces technology in learning is also required (Zhukov, 2013).

4.7 Technology in HE piano and other-than-piano learning

In the context of the traditional repertoire of Western classical music, several studies have investigated the perspectives of teachers, expert pianists and students on the use of technology in instrumental learning (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008). Other studies have examined the application of technology in instrumental learning combined with the perspectives of participants (Carey & Grant, 2015a; Zhukov, 2010). The types of technology used in these studies have varied: audio recording (Zhukov, 2010), video recording (Carey & Grant, 2015a; Daniel, 2001), MIDI protocols and piano roll visualization (Riley, 2005; Tomita & Barber, 2008), and instructional media (Benson, 1998). Other-than-piano learning studies have examined computer feedback when communicating basic emotions in guitar playing (Juslin, Karlsson, Lindstrom, Friberg, & Schoonderwaldt, 2006), and perspectives on the acceptance of computer or teacher feedback (Karlsson, Liljestrom, & Juslin, 2009).

A study conducted by Benson (1998) investigated the effects of different types of instructional media in small group piano lessons in HE. Student performance achievement and attitude were evaluated. Participants were 'music majors enrolled in a fourth semester piano class at The University of Texas at Austin. None of the students were piano majors' (Benson, 1998, p. 65). Sixteen piano students participated in this study in four groups, each consisting of four students. All the participants practised the same 'two keyboard theory exercises and two repertory pieces' three times over a two-week period (Benson, 1998, p. 73). The experimental design involved four treatment conditions for modelling undertaken by each group of participants: no use of media as a control group (no model); a MIDI-sequenced recording (aural model); video recording (visual model); and interactive multimedia computer program (multimedia model) (Benson, 1998, p. 66). Results revealed that all groups showed 'effective improvement of performance accuracy and achievement' for the proposed tasks in this study (Benson, 1998, p. 133). Likewise, no significant difference was found between the control and treatment groups in relation to 'note accuracy, voice leading, rhythm accuracy, or musicianship ratings' (Benson, 1998, p. 133). Although student performance achievements were found to be similar, practice with no media appeared to be more difficult than with media according to student ratings, as the multimedia seemed to assist learning (Benson, 1998).

The impressions of piano students on the usefulness of audio-visual feedback using MIDI technology were investigated by Riley (2005) in a study in USA. Three concert pianists recorded a nocturne by Chopin on a Yamaha Disklavier. These recordings were converted to piano roll graphs which showed deviations in dynamics, timing and articulation. Eight piano students in HE were asked to follow the piano roll graphs on a computer screen while listening to the performances. The students completed a questionnaire to evaluate the possible benefits of this kind of visual information on their piano learning. Students commented that the use of this technology might help in the following ways: to analyse what is happening in the performance; to correct errors quickly; to improve interpretation; and to develop a critical ear. The student responses suggested that the use of technology can improve the understanding of pieces and, consequently, enhance their own performances. In conclusion, the author recommended the use of this technology in one-to-one piano learning and teaching (Riley, 2005).

The perspectives of student pianists were examined in a UK research project which sought to evaluate the benefits that Computer Controlled Player Piano (CCPP) technology could bring to piano learning and teaching (Tomita & Barber, 2008). Eight first-study pianists were invited to take part in the study which gave the students lectures on how to use CCPP in their self-study. Findings indicated that students recognized the potential of CCPP in learning since they were able to self-assess through recording and playing back their performances. CCPP also enhanced their 'ability to work systematically and strategically' (Tomita & Barber, 2008, p. 138) through continuous use of this new technology. In addition, the use of MIDI interface seemed to allow visual information, which 'can be a good supporting adjunct to audio data, providing clear demonstration of detailed issues' (Tomita & Barber, 2008, p. 139). Although Tomita and Barber examined CCPP with students, the real context of its use combined with MIDI interface did not seem to be explored by their teachers working on student current repertoire. In addition, seminars on how to use CCPP prior to use can influence the perspectives of students on the benefits this new technology might bring them.

A new process of self-assessment using videotaping of music students was investigated in a study conducted in Australia (Daniel, 2001). Thirty-five instrumental and singing students in a conservatoire completed a questionnaire over one year. The frequency and types of feedback that students experienced before entering the university were investigated. Six categories of feedback were described by students: audio recording such as audiotaping; video recording such as videotaping; teacher comments; other student comments; audience comments; and family comments. Questionnaire results indicated that feedback on student performance was mainly in the form of teacher comments. Separately, students watched videotaped performances of themselves and were asked to write about their reactions, impressions, and any advantages and disadvantages of seeing their video-recorded performances. They also produced written self-reports on their performances. According to the student participants in this study, the use of video recording and written self-critical reports as a self-assessment approach had advantages and disadvantages. Examples of the benefits of video recording and writing self-critical reports were, respectively, ‘you can see the problems and try to fix them’ and ‘you learn to become more aware of what you’re doing and why’ (Daniel, 2001, p. 224). Examples of the drawbacks of this self-assessment approach were, respectively, that ‘people don’t like to be watched by cameras’ and that students reported a tendency to ‘often pick on yourself too much’ (Daniel, 2001, p. 224). Nevertheless, findings suggest that the use of video recording and self-critical reports can be a valuable tool for instrumental and vocal learning and teaching alongside teacher feedback in HE settings. This self-assessment approach, thus, can lead ‘to a greater level of student independence in assessing their performances’ (Daniel, 2001, p. 225).

Video recordings of lessons have also been used as a tool for conservatoire teachers to self-evaluate their pedagogical practices alongside a peer teacher in Australia (Carey & Grant, 2015a). In attempting to tackle certain issues in individual instrumental and vocal teaching, Carey and Grant (2015a, p. 63) explored a collaborative activity between peer teachers by introducing a ‘possible model for encouraging one-to-one teachers in conservatoires to reflect critically on their pedagogical choices and practices’. The lessons of participant teachers were video recorded and, based on transfer and transformative teaching approaches, the teachers watched their videoed lessons to reflect ‘critically on their teaching approaches and practices’ (Carey & Grant, 2015a, p.63). Findings showed that ‘the process of carrying out the activity of peer assisted reflection inspired a rethink of their teaching practices and approaches’ (Carey & Grant, 2015a, p. 70).

An investigation into the use of audio recording of student performances as a new approach to the self-assessment of music students in HE was conducted in Australia (Zhukov, 2010). Two HE level students participated in this study where workshop performances of a chosen piece were audio recorded. A Compact Disc (CD) enabled them to self-assess their own playing, and write 300-word self-reports on each of two subject-related aspects: technique and style. Participant student self-reports were discussed during lessons with their respective teachers. Feedback on these new activities was also given by participants. Findings of this study revealed that self-assessment using audio recordings gave students 'an opportunity to hear their performance and to have a calm reflection about it' while their written reports 'led them to identify problematic passages in the pieces and look for solutions' (Zhukov, 2010, p. 95). Findings seemed to contribute to the importance of student self-assessment in instrumental learning through the 'development of critical thinking, research skills, understanding of fundamental concepts and self-evaluation' (Zhukov, 2010, p. 95). Although the teacher and student pair discussed subject-related aspects from the reports, they did not listen to the audio recordings alongside each other during the lesson in this study. It is possible that the use of audio recording might also have been beneficial for learning as well as changing both student and teacher perceptions of the performance while they were listening to the recording, since both student and teacher were focusing only on listening rather than on playing.

In a research project called Feedback-learning of Musical Expressivity (Feel-ME), Juslin et al. (2006) developed and implemented computer software to enhance the expression and communication of emotions in musical performance. Three groups of jazz/rock guitar players received three types of feedback after performing a simple melody under four expressive emotions: happiness, sadness, anger, and fear. The types of feedback were: computer feedback for articulation, attack, loudness, tempo, and timbre; teacher feedback with no modelling allowed; and absence of feedback. The results of this project were based on listener ratings of the communication of emotion by the guitar players for each feedback condition. Findings suggested that emotions were communicated in the presence of feedback rather in the absence of feedback. In addition, computer feedback was more effective than teacher feedback in improving this task, because computer feedback 'focused solely on the acoustic cues used to express each emotion', whilst teacher feedback 'often included information that was irrelevant to the task' (Juslin et al., 2006, p. 91). Some advantages of this approach were its applicability to melodic instruments such as violin and flute, and brief extracts of music. In contrast, some limitations of this approach were its non-applicability to harmonic instruments, such as piano and for long extracts of music. However, advantages of this feedback system over traditional teaching were reported to be: the development of critical feedback in a comfortable environment; its usability; applicability for individual self-learning and providing a useful description of the relations between 'expressive intentions, acoustic cues, and listener impressions' (Juslin et al., 2006, p. 92).

The acceptability to students of computer-produced feedback using the approach developed by Juslin et al. (2006) was investigated further by Karlsson et al. (2009). In this Swedish research, an investigation was undertaken into performer impressions of the quality of feedback given by a computer program and by teachers when seeking to improve the expression of emotion in the performances. Eighty electric guitar players were asked to play the same short melody to express four emotions, happiness, sadness, anger and fear. Feedback from the computer program and written and verbal feedback from the teacher evaluated only happiness and fear. Four sets of feedback were shown to the performers. Two true sets of feedback were provided: computer generated and teacher feedback. Two fake sets of feedback were also given: computer generated feedback verbalized by a teacher; and verbal teacher feedback presented in writing by a computer. Although both types of feedback, true and fake, were perceived as easy to comprehend, performer impressions of the quality of teacher feedback were more positive than those given by computers in the true situation. Teacher feedback was rated higher than computer feedback because the former 'provided encouragement, examples and explanations', while the latter 'was short, concise and focused only on the acoustic cues of primary importance of the communicative feedback' (Karlsson et al., 2009, p. 186). Results indicated that 'regardless of the actual efficacy, teacher-produced feedback was usually perceived as more attractive by the performers than computer-produced feedback' (Karlsson et al., 2009, p. 186).

All the above studies reported that the use of technology, such as audio recording (Zhukov, 2010), video recording (Carey & Grant, 2015a; Daniel, 2001), MIDI technology through piano roll graph (Riley, 2005; Tomita & Barber, 2008), computer-based feedback (Juslin et al., 2006; Karlsson et al., 2009), and several other types of instructional media technology (Benson, 1998) appears to be beneficial in HE piano and other-than-piano learning. The most relevant benefits are: increased conscious-awareness of performances (Daniel, 2001; Riley, 2005; Zhukov, 2010), and development of performer autonomy and responsibility for learning through self-evaluation, self-reflection and critical thinking (Carey & Grant, 2015a; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010).

In these studies, students reported their views on the benefits of these new approaches. Students were able to gain a better understanding of what was happening in their performances (Daniel, 2001; Riley, 2005; Zhukov, 2010), develop self-critical listening skills (Riley, 2005; Zhukov, 2010) and self-evaluate through reflective and critical thinking (Daniel, 2001; Tomita & Barber, 2008; Zhukov, 2010). In addition, students also commented that technology promoted a simpler way of identifying and finding a solution to their performance problems (Daniel, 2001; Zhukov, 2010), improving their interpretation (Riley, 2005; Zhukov, 2010), and also making learning an easier process when using technology instead of none (Benson, 1998). Limitations of computer-produced feedback appeared to be related to its application to melodic instruments and short pieces only (Juslin et al., 2006). Also, computer-based feedback did not seem to be attractive to performers when compared with teacher-produced feedback (Karlsson et al., 2009). However, computer-produced feedback has been shown to be easily available and applicable to individual learning (Juslin et al., 2006).

Whilst the application of technology based on student self-reports and self-assessment has been investigated (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010), the use of technology for enhancing the learning potential of student performance within a one-to-one piano studio by observing videoed lessons alongside teacher and student reports seems to be under-researched. Several research studies have investigated the application of technology in terms of RTVF in other-than-piano studios such as singing and percussion as discussed below.

4.8 Real-time visual feedback in instrumental and vocal learning and teaching

The use of technology in the form of RTVF in instrumental and vocal learning and teaching has received increasing research attention (Brandmeyer, 2006; Sadakata et al., 2008; Welch, 1983, 1985b; Welch et al., 2005). One strand of research has investigated the use of RTVF in tapping and percussion learning (Brandmeyer, 2006; Sadakata et al., 2008), while another addressed the benefits and limitations of the use of new technologies in a singing studio (Welch, 1983, 1985b; Welch et al., 2005). The types of technology used in these studies included video recording and spectrographic displays (Welch, 1983, 1985b) and specifically designed software programs for voice (Welch et al., 2005), tapping (Sadakata et al., 2008), and percussion (Brandmeyer, 2006). The research studies in RTVF most relevant to the current study are reviewed in the following paragraphs.

Welch (1983, 1985a, 1985b) was one of the first researchers to conduct studies using RTVF technology in vocal learning and teaching. The study (1983, 1985a, 1985b) aimed to examine child singers who customarily attended group singing lessons; this made evaluation of individual child singers more difficult. The effects of variability of practice and knowledge of results (KR) were investigated in a singing studio setting so as to evaluate learning to pitch in primary education (Welch, 1985b). The participants in this study were sixty six female and male children aged from 7-8 years old who demonstrated difficulties in singing in-tune when singing two simple task melodies. Participants were grouped according to their ‘sex and degree of [vocal] disability’ (Welch, 1985b, p. 240). Each child was tested individually in the experiment. A range of technical equipment was used in this study: laryngograph, electrodes, oscilloscope, earphones and cassette recorder. The children were asked to listen to the pitch stimuli, which were played on a cassette. Then, the children received the instruction to imitate by singing the sound to which they had listened. During singing, the frequency of the pitch produced by the child was sent to a laryngograph, which was connected to an oscilloscope screen. The extracted pitch variations could then be visualized in terms of lines moving ‘upwards and downwards’ (Welch, 1985b, p. 241). The graph produced on the screen showed lines, which represented the pitch as vocalized by the child.

This visual feedback in real-time was one of the variables in the study. The second variable was KR, which ‘is made by a source external to the child, and provides a measured outcome of the response’ by providing coloured targets on the screen (Welch, 1985b, p. 239). The third variable was the variability of practice, which related to the number of different pitch stimuli to be imitated. Three treatment conditions were used for this experiment: no visual feedback and no KR; visual feedback and no KR; and visual feedback and KR. The findings of the study revealed that: the learning of pitch accuracy appeared to occur when ‘qualitative information about the pitch error’ (Welch, 1985b, p. 246) was available to the child, that is, when visual feedback was combined with KR, and when there was ‘sufficient practice for this information to be applied’ (Welch, 1985b, p. 246).

The use of a particular technology was also tested to enhance feedback in vocal learning and teaching in HE settings. A new technology for RTVF in the singing studio was developed for a study conducted in the UK (Welch et al., 2005). Vocal learning technology (VOXed software) developed in a project with the same name designed for PC Windows, was tested in two different sites in England. This technology system was ‘capable of analysing sound captured by a microphone’ and subsequently provided RTVF on several singing performance parameters such as ‘input waveform, fundamental frequency against time’ (Welch et al., 2005, p. 233). The technology also involved the use of a web camera which provided ‘visual feedback regarding the singer’s posture and general physical gesture during performance’ (Welch et al., 2005, p. 233). At each research site there was one singing teacher and four students. Within each group of students, two had singing lessons with the application of the VOXed software, whilst the other two students were controls and did not have the RTVF technology applied to their lessons. This study followed previous work where Welch (1983, 1985a, 1985b) developed two models to characterize the singing learning process for pitch accuracy.

In Figure 4.1, parts (a) and (b) show both models of singing learning. Part (a) represents a traditional teaching process, whilst part (b) shows the teaching process with additional visual feedback (Welch et al., 2005). Figure 4.1 (a) identifies two key moments for students following traditional singing pedagogy over time. First, '[t]he challenge for the student is for teacher's 'post-hoc' verbal feedback to be interpreted and translated subsequently into an adapted singing performance' (Welch et al., 2005, p. 227). Second, 'possible critical periods' are identified 'in the processing of information prior to and after the provision of feedback and any subsequent action', for example after the first vocal response and before the second, subsequent vocal response (Welch et al., 2005, p. 228). Figure 4.1 (b) shows modification of the feedback process in singing teaching where there is a 'provision of a real-time visual metaphor of vocal pitch change on the computer screen' (Welch et al., 2005, p. 228). This technology-generated modification of feedback attempts to minimize the possible critical periods in the processing of information in the singing learning model.

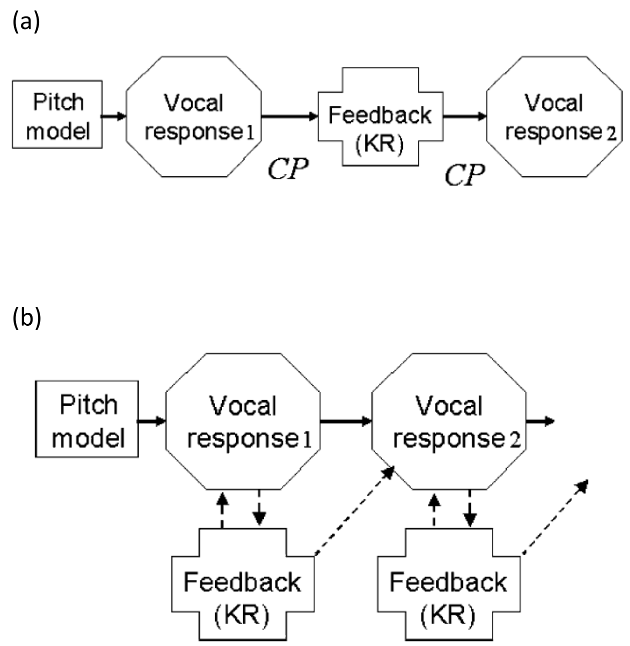


Figure 4.1 Models of singing learning: (a) in a traditional teaching process; and (b) in a teaching process with additional visual feedback (Welch et al., 2005, p. 228)

Key: CP represents critical periods; KR represents knowledge of results.

The singing lessons were audio and video recorded using new technology. There were two stages of lessons for each teacher-student pair: the first stage was the lesson with no technology, and the second stage was the lesson with technology. The first stage was described as 'an early fieldwork observation prior to technology being introduced (and assumed to be a baseline teacher behaviour for each focus student)' (Welch et al., 2005, p. 235). Observations of lessons and interviews with the teacher and students at each site supported the collection of data for further analysis. Teacher behaviours were categorized into seven types: 'accompanying the student, conversation, demonstration, instruction, listening, marking a feature and activity not related to the lesson (such as non-singing focused discussion)' (Welch et al., 2005, p. 236). Student behaviours were classified under four categories: 'conversation (interacting with the teacher), listening, performing and other activities that were not directly related to the lesson' (Welch et al., 2005, p. 238). Regarding teacher behaviours, there were found to be, 'significant differences between the basic pedagogical approaches of the two teachers' without the technology (Welch et al., 2005, p. 237) while 'the effects of having the technology available in the singing lesson varied with the individual teacher' (Welch et al., 2005,p. 238). Thus, the pedagogical approach and the time spent using technology in the lesson varied for each individual teacher.

With regard to student behaviours, in this same study, Welch et al. (2005) argued that students performed more and spent less time listening to teacher talk when technology was applied, and student behaviours in lessons without technology involved more listening and conversation and less performance. Different feedback display options were offered by the technology in the study, in the form of on-screen information for use by the teacher: frequency contour display, spectrograms in full colour or white and black, videos of student performances, and vocal tract displays. Some of the simple displays provided information on 'a specific aspect of singing (such as pitch, timbre and resonance)' (Welch et al., 2005, p. 241). Of the complex displays, spectrograms provided information about 'vowel quality, length of vowels and consonants, vocal register transitions, and interactions between loudness (intensity) and tone quality' (Welch et al., 2005, p. 241). One of the teachers used the spectrogram innovatively to provide 'visual feedback on a student's breathing behaviours' (Welch et al., 2005, p. 241).

Findings of the study (Welch et al, 2005) revealed that this new technology might benefit vocal learning and teaching. The visualized voice outputs, such as a spectrogram, appeared to facilitate discussion between teacher and student on captured student performance since data was recorded, saved, and available to be played back through this specific software. Both of the teachers reported a positive interest in using Voxed software and agreed that it did not appear to disrupt the normal course of their teaching. However, apart from the advantages shown by the use of this technology, the differences in individual teaching strategies were also considered in order to use this new technology in a singing studio. The results of this RTVF study indicated that 'new technology can impact positively on teacher behaviours and student experiences by providing more meaningful feedback through an enriched pedagogy' (Welch et al., 2005, p. 225).

The role of RTVF has also been investigated in a study of imitation of rhythms by percussion students in the Netherlands (Brandmeyer, 2006). The effect of two different visual representations was evaluated during RTVF in a drum studio. Eighteen drum students from a conservatoire were asked to imitate rhythm patterns under three conditions: analytic, holistic, or control in terms of no visual feedback. Two rhythm patterns in three different expressions, on-the-beat, laid-back, and rushed, were recorded by an expert drum teacher so as to be used as the target performance material to be imitated by the students. While the students imitated the rhythm patterns, they also received RTVF. Apart from the control condition where students did not receive visual feedback from display technology, two types of RTVF were available to students: analytic and holistic. The analytic visual feedback demonstrated a visual representation similar to a musical score where each line represented one instrument, timbre or note: 'the bass drum is the pink square, the snare is the green circle, and the hi-hat is the blue triangle' (Brandmeyer, 2006, p. 34). The holistic visual feedback 'was based on the expressive styles' (Brandmeyer, 2006, p. 36). Parallelograms leaning to the front or to the back were chosen to represent rushed and laid-back styles, respectively, while a rotated square was chosen to represent an on-the-beat style. The similarity between the two types of visual feedback was in their visual representation where the 'target appeared in the background as grey shapes, while the imitation notes appeared as coloured transparent shapes on the top of targets' (Brandmeyer, 2006, p. 34). Students also completed a questionnaire about their age, drumming practice, and experience with visual feedback. The findings of this study demonstrated that student imitation performance with no feedback was similar to the analytic RTVF; and different from the holistic RTVF condition. A contradiction in student comments on the application of this approach was found. Some participants said that they 'felt that the visual feedback was a distraction from what was essentially a task involving audition and motor skills', while others commented that 'the visual feedback was quite helpful, and that, if it were available in a school- or home-setting, they would enjoy being able to use the visual feedback for practising' (Brandmeyer, 2006, p. 19). The majority of students reported their preference for analytic rather than holistic visual feedback because the former was easier to understand. Students commented that they had previous familiarity with the rhythm patterns. The holistic visual feedback appeared to show an increase in expressivity in student imitation performance when compared to the other two conditions (analytic and no feedback). Otherwise, neither of the two visual feedback types appeared to benefit learning or improve timing in student imitation performance. In conclusion, the results of this study indicated that the type of visual feedback appeared to influence the increase of expressive features in overall performance and the rate of improvement in performance accuracy.

The use of technology for RTVF for tapping was examined in imitation and perception tasks of short rhythms (Sadakata et al., 2008). Twenty-four amateur musicians who had formal training in music were divided into two groups, with RTVF and without RTVF. Participants were asked to imitate two-bar rhythms. The imitation task of short rhythms varied four times for each of the two acoustic parameters: loudness or dynamics, and timing. In addition, the study evaluated the possibility of a transfer of learning described as 'a process in which learned skills are transferred to novel materials and tasks' (Sadakata et al., 2008, p. 208). In this case, the transfer of learning was investigated from an imitation task to a perception task. The findings demonstrated that the use of this RTVF system improved imitation of loudness, but did not facilitate the imitation of timing patterns. Another result indicated that transfer of learning appeared to occur within the same task of imitation, but it did not appear to transfer from the first task, imitation, to the second, perception (Sadakata et al., 2008, p. 217). In addition, RTVF did not appear to affect the transfer of learning.

Research studies using RTVF in musical learning and teaching appear to have different findings, depending on the instrument, performance task and type of technology that was used in the instrumental and vocal lessons. In previous research in other-than-HE settings, Welch (1985b) reported that pitch accuracy in vocal learning and teaching appeared to be enhanced in at least one of the following three conditions was available: KR provided, visual feedback technology was combined with KR, or variability of practice was provided. Two decades later, a new RTVF technology also appeared to benefit vocal learning and teaching, but now in HE settings (Welch et al., 2005), although pedagogical approaches do appear to be an individual characteristic of teachers with or without the application of technology in singing studios. In addition, it is possible that the type of visual representation might, for some students such as percussionists, interfere with instrumental learning and teaching designed to imitate short rhythms using RTVF (Brandmeyer, 2006). RTVF did not appear to improve imitation of timing of short rhythms in percussion performance (Brandmeyer, 2006), or in tapping (Sadakata et al., 2008). However, RTVF appeared to improve imitation of dynamic aspects in tapping short rhythms (Sadakata et al., 2008), but not in percussion performance (Brandmeyer, 2006).

4.9 Real-time visual feedback in piano-related studies

Several types of technology have been applied to piano-related studies in order to investigate different research purposes (François, Chew, & Thurmond, 2007; McPherson, 2013). The application of MIDI technology has been used as a measurement mean for musical performance practice assessment when a compatible digital piano is also used (Himonides, 2012). In this way, MIDI technology encompasses data with regard to 'every stroke on the keyboard' (Himonides, 2012, p. 450) including the correspondent pitch of each played key or note, length of time for which each key or note was pressed and released, and velocity with which the key or note was pressed (Himonides, 2012). In addition, similar parameters for the action of the pedals can also be measured such as pedal level or height, and pedal pressing and releasing time for the damper (sustain) pedal or una corda (soft) pedal.

The first piece of technology which was perhaps used with piano performance and RTVF was called the *Moog PianoBar* was 'designed by Don Buchla in 2001 and sold by Moog Music 2003-2007' (McPherson, 2013, p. 152); this technology 'used optical reflectance sensing to measure the white keys and beam-interruption sensing on the black keys' (McPherson, 2013, p. 153). The *Moog PianoBar* promised to be an alternative to either the less available 'MIDI-enabled pianos such the Yamaha Disklavier or Boesendorfer CEUS' (McPherson, 2013, p. 152), or the more commonly available MIDI-compatible digital pianos. This technology '[enabled] a performer to use their desired concert instrument whilst also enabling researchers to acquire valuable real-life performance data at concert' (Himonides, 2012, p. 451). Although the *Moog PianoBar* was a versatile piece of technology as it provided measurements of 'MIDI from a conventional acoustic instrument' (McPherson, 2013, p. 152), its production was discontinued. An alternative to replace the discontinuity of the *Moog PianoBar* was a technological device designed by McPherson, who presented a 'portable optical measurement system for capturing continuous key motion on any piano' (McPherson, 2013, p. 152). This technological device has the potential to 'provide rich visual feedback to assist the performer in interacting with more complex sound mapping arrangements' (McPherson, 2013, p. 152) through a multicolour-system alongside the keyboard through red, green and blue LEDs.

Another piece of technology called *Mimi* was designed to explore 'the use and effectiveness of visual feedback in improvisation planning and design', where auditory and visual feedback were available simultaneously (François et al., 2007, p. 277). RTVF as a piano roll form of notation was familiar to the participants and was available to the pianist while improvising, by providing 'the performer with instantaneous and continuous information on the state of the system' (François et al., 2007, p. 278). The design of this technology suggests the benefit of a 'musical improvisation system that explores the potential and powerful impact of visual feedback in performer-machine interaction' (François et al., 2007, p. 280).

Previous research studies tended to explore the use of RTVF in piano studies such as piano performance (McPherson, 2013), and piano improvisation (François et al., 2007). In these studies not only visual, but also auditory feedback in real-time was available for the piano performer in the form of a multicolour system. Both cited studies reported the potential benefits of visual feedback for pianists when having RTVF available. However, as of yet, no study seems to have explored RTVF in piano learning and teaching.

4.10 Synthesis of feedback in one-to-one instrumental and vocal learning

This section shows the synthesis of feedback in one-to-one instrumental and vocal learning in HE and other levels of expertise. Feedback in musical performance learning can be expressed in any form of verbal behaviour, for instance verbal comments or non-verbal behaviour, including pointing to the musical score. Both verbal and non-verbal behaviour can be related to musical performance parameters such as articulation, dynamics, tempo and fingering. Feedback can be delivered either by teachers when providing information, giving directions, and asking questions, or by student self-evaluation. The two tables below show the synthesis of verbal feedback (Table 4.2) and non-verbal feedback (Table 4.3) which were compiled from the current literature review. An additional table (Table 4.4) shows the types of musical performance parameters which were discussed in lessons when technology was applied in instrumental and vocal learning and teaching environments.

Types of verbal and non-verbal behaviours including feedback have been investigated in previous studies on instrumental and vocal learning and teaching for observing lessons (see, for example, Benson & Fung, 2005; Burwell, 2010; Welch et al., 2005). A synthesis of types of verbal feedback in instrumental and vocal learning and teaching (see Table 4.2) generated the following sub-categories: giving directions; asking questions; providing information; giving verbal feedback (positive, negative, or neutral); and off-task comments (see, for example, Benson & Fung, 2005; Burwell, 2010; Siebenaler, 1997; Speer, 1994; Welch et al., 2005).

A synthesis of the types of non-verbal feedback in instrumental and vocal learning and teaching (see Table 4.3) generated the following sub-categories: playing alongside the student; modelling such as playing, or singing; imitating student performance; making hand gestures; giving non-verbal feedback such as smiling, laughing, nodding, shaking, and facial expressions; and conducting or tapping the pulse (see, for example, Benson & Fung, 2005; Burwell, 2010; Siebenaler, 1997; Speer, 1994; Welch et al., 2005).

In addition, a list of musical performance parameters which were assessed through the use of technology has been reported in a number of research studies (see Table 4.4). The following sub-categories were also generated: overall performance; timing; dynamics; articulation; timbre; tempo; communication of emotion; rhythmic accuracy; pitch accuracy; and frequency contour.

Overall, the types of verbal and non-verbal behaviours including feedback and the musical performance parameters related to them which have been reported in the literature can be summarized in the three tables below.

Table 4.2 Synthesis of verbal feedback in instrumental and vocal learning and teaching

Verbal (synthesis)												
Teacher							Student					
	Teacher (synthesis)							Student (synthesis)				
Sources and original categories	Giving directions	Asking questions	Providing information	Giving verbal feedback (positive/ negative/ ambiguous)	Writing on the score	Off task comments	Sources and original categories	Asking questions	Providing information	Other verbal interaction	Writing on the score	Off task comments
Benson and Fung (2005): teacher verbalization (directives, information, analogies, positive specific feedback, positive non-specific feedback, negative specific feedback, negative non-specific feedback, and teacher questions)	√	√	√	√			Benson and Fung (2005): student question, verbal response to teacher question,	√	√			
Burwell (2010): information; elicitation (questioning); feedback; writing on the score; coaching with student playing		√	√	√	√		Burwell (2010): information and elicitation (back channelling and questioning); joking; apologising; writing on the score	√		√	√	
Creech (2011): teacher talk, teacher questioning; teacher feedback (attributional or non-attributional; positive or negative)		√	√	√			Creech (2011): pupil talk.	√				
Duke and Buckner (2009): teacher verbalization (directives; information statements; negative feedback; positive feedback, questions)	√	√	√	√			Duke and Buckner (2009): student answering; student questioning.	√	√			
Duke and Henninger (1998): directive statements; negative feedback statements	√			√								
Gaunt (2007): discussing aspects of playing (such as posture); questioning; giving feedback		√	√	√								
Karlsson and Juslin (2008): verbal instruction; outcome feedback (non-specific); metaphors	√			√								
Kostka (1984): teacher talk; teacher instruction; teacher performance ([physical representation of music - see below under non-verbal]: writing notes); teacher 'reinforcement' (social approval; academic approval; social disapproval; academic disapproval; reinforcement error)	√		√	√	√		Kotska (1984): student talk; student performance ([physical representation of music]: writing notes)		√		√	
Siebenaler (1997): general directions; specific directions; questions; music talk; general directive; specific directive; specific approval; general approval; specific disapproval; general disapproval; approval mistake; disapproval mistake; off-task	√	√	√	√		√	Siebenaler (1997): verbal response; questions; music talk; off-task;	√		√		√
Speer (1994): academic musical task presentation (comments, information); direction (ask to play); social task presentation; off task; teacher feedback (verbal approval and verbal disapproval/ specific feedback and non-specific feedback; counting beats)	√		√	√		√	Speer (1994): student response (verbal: asking or answering questions, making statement).	√	√	√		
Welch et al. (2005): conversation; instruction; marking a feature; non-singing activities	√		√	√		√	Welch et al. (2005): conversation; non-singing activities		√			√

Table 4.3 Synthesis of non-verbal feedback in instrumental and vocal learning and teaching

Non-verbal (synthesis)														
Teacher								Student						
	Teacher (synthesis)								Student (synthesis)					
Source and original categories	Playing alongside the student	Modelling (playing/ singing)	Imitating student playing	Making hand/ body gestures	use of rehearsal space	Non-verbal feedback (smiling/nodding)	Inactive	Source and original categories	Playing/ singing/ clapping	Making gestures	Self-touching (face)	Using technology	Use of rehearsal space	Inactive
Benson and Fung (2005): teacher modeling (teacher play, play with student, gestures, gestures with student play, singing, singing with student play, multiple modeling, multiple modeling with student play, and off-task)	√	√	√	√	√		√	Benson and Fung (2005): student play, student sing, and off task	√					√
Burwell (2010): use of physical gesture; use of posture; use of space; singing; modeling; imitation; conducting; smiling; laughing; touching the student's instrument; touching the score	√	√	√	√	√	√		Burwell (2010): performance modeling (rehearsal, preparation, practice, and exercise); self-touching; use of physical gesture; use of posture; use of space; singing; conducting; smiling; laughing	√	√	√		√	
Creech (2011): scaffolding (modeling and singing; playing along; accompanying on the piano)	√	√						Creech (2011): pupil playing	√					
Duke and Buckner (2009): teacher modeling		√						Duke and Buckner (2009): student playing	√					
Gaunt (2007): playing along, modelling	√	√												
Karlsson and Juslin (2008): modelling	√													
Kotska (1984): teacher performance (piano playing, clapping)	√							Kotska (1984): student performance (piano playing, clapping); non-musical activity (preparing the music or adjusting the bench)	√				√	
Siebenaler (1997): clap/sing (clap, sing, conduct or count); play (or play along); inactive	√	√					√	Siebenaler (1997): play; clap/sing (clap or sing); inactive	√					√
Simones et al. (2013): musical beats, conducting style, playing piano, mimic, touch	√	√	√	√										
Speer (1994): academic musical task presentation (teacher modeling-playing, singing, tapping)		√						Speer (1994): student response (performance: playing; singing; or tapping	√					
Welch et al. (2005): accompaying, demonstrating	√	√						Welch et al. (2005): listening, performing, using technology	√			√		√

Table 4.4 Synthesis of feedback by technology and assessed musical performance parameters in instrumental and vocal learning and teaching

Technology (synthesis)																				
											Singing aspects									
Technology (by source & original details)	Articulation	Communication of emotions	Dynamics (loudness)	Overall performance (style)	Pitch accuracy	Rhythm accuracy	Technique	Tempo	Timbre	Timing	Touch (tone quality)	Breathing behaviours	Frequency contour	Resonance	Vowel quality, length of vowels and consonants, vocal register transitions	Computer feedback*	Teacher feedback	MIDI parameters	Post-hoc feedback	Real-time feedback
Brandmeyer (2006): two different visual representations (imitation of rhythm)			√			√			√	√						(√)				√
Daniel (2001): video recording with self-critical report				√														√	√	
Juslin et al. (2006): computer feedback (tempo, sound level, articulation, timbre, communication of emotions)	√	√	√					√	√							√	√		√	
Karlsson et al. (2009): computer feedback		√														√	√		√	
Riley (2005): piano roll visualization (deviations on dynamics, timing, and articulation)	√		√	√						√									√	
Sadakata et al. (2008): one visual representation (imitation of rhythm on dynamics and timing)			√			√			√	√						(√)				√
Tomita and Barber (2008): computer controlled player pianos (CCPP)			√			√												√		√
Welch (1985): laryngograph, electrodes,oscilloscope, earphones, and cassete recorder					√											(√)	√			√
Welch et al. (2005): spectogram (in full color or black and white), digital video recording, and vocal tract display			√		√				√		√	√	√	√	√	(√)	√			√
Zhukov (2010): audio recording with self-critical report				√			√												√	

Key: √ is used for verbal feedback provided by the computer and (√) is used when the computer screen provides information about the student performance.

The tables above present syntheses of verbal feedback, non-verbal feedback, and technology assessed musical performance parameters in selected studies. Synthesis of verbal feedback show that in previous research studies verbal feedback could be categorized into that provided by the teacher and student. Teachers were found to: provide information, give directions, ask questions, offer general feedback, positive, negative, or ambiguous, and give written feedback by writing on the score as well as making off-task comments. Students mainly asked questions, provided information, entered into other verbal interaction such as making statements and apologising in addition to writing on the score and making off task comments. The synthesis of non-verbal feedback provided a set of behaviours; these have been commonly observed in previous research studies in one-to-one instrumental and vocal learning and teaching environments. Teachers tended to play alongside the student, model playing and singing, imitate student playing, make hand or body gestures, use of the rehearsal space, give non-verbal feedback notably by smiling, nodding, and head shaking head, and through remaining inactive. Students tended to play, sing or clap, make gestures, touch their face, use technology such as the metronome, use of the rehearsal space, and also remain inactive.

The majority of research studies into instrumental and vocal learning which used technology devices such as audio recording (Zhukov, 2010), video recording (Daniel, 2001), graphic visualization of performances studies (Brandmeyer, 2006; Riley, 2005; Sadakata et al., 2008; Tomita & Barber, 2008; Welch, 1983, 1985b; Welch et al., 2005) and computer feedback (Juslin et al., 2006; Karlsson et al., 2009) had different purposes. For example, some studies in vocal learning sought to improve pitch accuracy, tone quality, and breathing behaviours alongside other musical performance parameters (Welch et al., 2005). Other studies involving graphical visualizations of performances aimed to show students that the overall performance (Daniel, 2001; Riley, 2005; Zhukov, 2010), timing (Brandmeyer, 2006; Riley, 2005; Sadakata et al., 2008), dynamics (Brandmeyer, 2006; Juslin et al., 2006; Riley, 2005; Sadakata et al., 2008; Tomita & Barber, 2008; Welch et al., 2005), articulation (Riley, 2005), timbre

(Brandmeyer, 2006; Juslin et al., 2006; Sadakata et al., 2008; Welch et al., 2005), rhythmic accuracy (Brandmeyer, 2006; Sadakata et al., 2008; Tomita & Barber, 2008), technique (Zhukov, 2010), and communication of emotions (Juslin et al., 2006) could be assessed by using technology.

4.11 Summary

This chapter has reviewed two forms of interpersonal feedback in several learning and teaching contexts: between individuals, specifically music teachers and students, and (virtually) between individuals and technology in instrumental and vocal learning. First, interpersonal feedback was reviewed in recent research studies for conventional instrumental and vocal learning settings such as in HE, and other-than-HE settings, in one-to-one tuition, and in small groups, particularly in a piano studio context. The content of musical practice was reviewed by examining musical performance parameters usually worked on in piano learning, performance, and practice, such as dynamics, articulation, and timing, including technology parameters used to measure these aspects of musical performance. Interpersonal feedback between individuals and technology was also reported in this chapter by focusing on the use of varied types of technology in music education, the application of technological devices in piano lessons, and the specific use of RTVF technology in instrumental and vocal learning.

One-to-one instrumental and vocal learning have the advantage of providing personalized learning, while having the disadvantage of being teacher dominated most of the time (Creech & Gaunt, 2012), especially in the master-apprenticeship model (Hallam, 1998; Jørgensen, 2000). One challenge to the disadvantages of one-to-one music tuition is the use of technology which can bring about transformative change in this traditional teaching style (Creech & Gaunt, 2012). Effective piano learning and teaching appeared to be dependent on specific feedback (Kostka, 1984; Siebenaler, 1997; Speer, 1994), and was shown to be characterised by short student performance episodes and more frequent teacher feedback or teacher performance in the lessons (Duke & Buckner, 2009; Siebenaler, 1997). Although general feedback was shown to be the most frequent style of teacher feedback (Karlsson & Juslin, 2008), specific feedback appeared to contribute to student autonomy in other-than-piano lessons, particularly in violin lessons (Creech, 2012). This was independent of whether or not the type of specific feedback was positive or negative (Duke & Henninger, 1998, 2002). Small group piano lessons appeared to provide more feedback when compared to one-to-one piano lessons, and were reported as developing student responsibility for learning and critically thinking about their performance (Daniel, 2003, 2006).

Instrumental and vocal learning and teaching in HE appeared to be dependent on a circular interaction between teacher and student (Burwell, 2010) in an environment where teacher-student interactions are complex (Gaunt 2011). It was reported that the teacher usually dominates while student talk is minimal in the lesson (Bryan, 2004), that teachers want their students to be independent and autonomous in their learning (Gaunt, 2007), and that students want teachers who are able to develop their autonomy and independence in learning (Gaunt, 2009).

The use of technology in music education was shown to be often beneficial in the music classroom (Savage, 2007), in HE music studios (King 2008), and in instrumental or vocal learning (Zhukov, 2013). There was evidence that technology use can promote a change in learning from a traditional to transformative pedagogical approach (Savage, 2007) by stimulating a more collaborative environment between individuals who are using the technology (King, 2008), especially with students who have been increasingly embracing technology in their lives (Zhukov, 2013).

The use of technology was found to be valuable in most of the research studies reported in piano and other-than-piano learning. Audio recording (Zhukov, 2010), video recording (Daniel, 2001), MIDI technology through piano roll graphs (Riley, 2005; Tomita & Barber, 2008), computer-based feedback (Juslin et al., 2006), and several instructional media technologies (Benson, 1998) were considered to have benefits for instrumental and vocal learning. Particularly relevant benefits included the use of technology to increase conscious-awareness of performances (Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010), and to develop student autonomy and responsibility for learning through self-evaluation, self-reflection and critical thinking (Carey & Grant, 2015a; Riley, 2005; Zhukov, 2010).

RTVF technology appeared to be beneficial when combined with feedback in the form of KR, and when applied to variability of practice among children in singing studios (Welch, 1983, 1985a, 1985b). In the HE singing studio, the application of RTVF varied across teachers in their individual pedagogical approaches and lesson time spent using technology (Welch et al., 2005). However, the type of visual representation of RTVF has an effect on the performance outcome when students imitate a rhythmic pattern in percussion learning (Brandmeyer, 2006), and the imitation can be more accurate for particular types of musical performance parameters than others such as dynamics rather than timing (Sadakata et al., 2008). RTVF in piano-related studies indicates the potential of recently designed technological devices (François et al., 2007; McPherson, 2013) for prospective applications in piano performance (McPherson, 2013), and experimental uses in piano improvisation (François et al., 2007).

In Chapter 5, the methodology of this study is discussed; this includes an overall summary of the theoretical framework and empirical research design.

5 Methodology

5.1 Introduction

Chapter 5 presents an overview of the methodology adopted in this study. A summary of the theoretical framework is presented and the research questions revisited. Unlike this earlier research which used case study, experimental or action research approaches, this chapter focuses on the adoption of an exploratory action case-study approach used in the current study. The development of the methodology leading up to the final research design is discussed in the pilot studies. The multiple sources of collected data are reported together with details of the participants and their background, materials, video recordings, interviews, and technology-generated MIDI data. A review of ethical issues is also provided here. The chapter continues by reporting the analyses of video, music and interview transcriptions and the use of computer-assisted qualitative data analysis (CAQDA). The chapter then discusses multi-method data analyses of video, MIDI, and interview data. The video data were analysed using three approaches: thematic analysis for behaviours, thematic analysis also for pedagogical uses of technology, and microstructure analyses. Microstructure analyses of musical behaviour in videoed lessons, such as musical practice and listening back, were analysed in terms of additional auditory feedback. MIDI data were analysed in terms of the additional visual feedback provided in lessons. Next, interview data were analysed by using thematic analysis of participant perspectives on the use of technology-mediated feedback; this could be compared with the thematic analysis obtained in the video recordings. The chapter concludes by discussing the trustworthiness of the study and the four quality criteria necessary in qualitative research—credibility, transferability, dependability, and confirmability, as proposed by Guba (1981)—as drawn upon in this study. Chapters 6 to 10 present and interrogate the findings of each data analysis approach used in this study.

5.2 Theoretical framework summary

The nature and significance of feedback has been reported in Chapters 2, 3, and 4 in the contexts of motor control and learning, intrapersonal feedback in studies which investigated solo piano learning, playing, and memorization, duet synchronization, and interpersonal feedback in one-to-one instrumental and vocal lessons between teacher and student and between technology and individuals.

The advantages of using technology in enhancing the motor control, learning, and performance of an individual have been reported in several studies and reviews (e.g. Magill, 1989; Schmidt & Lee, 2011). Such techniques in using augmented feedback, including watching videotape replays and graphic representations of performances, can facilitate learning and enhance motor performance, depending on the expertise level of the learner and for particular performance features which are observed quickly and easily discerned when they are visually displayed (Magill, 2014). The type of technology involved in some studies seemed to be beneficial mainly when combined with KR or KP, such as verbal feedback provided by coaches or teachers with defined performance goals (Kernodle & Carlton, 1992; Wallace & Hagler, 1979), rather than when no verbal feedback was provided by an instructor (Schmidt & Lee, 2011). This variation is due to the complex set of information that the video recording of performances provides to the learner (Schmidt & Lee, 2011).

An increasing number of research studies in the last few decades have investigated the roles of auditory, visual, and proprioceptive feedback in piano studies, such as in sight-reading, memorization, rehearsal or performance, ensemble synchronization, and in learning unfamiliar pieces (e.g. Bishop & Goebl, 2015; Finney & Palmer, 2003; Furuya & Soechting, 2010). These previous studies in intrapersonal feedback have been crucial in understanding which types of feedback are inherently meaningful to the piano learner, as well as in understanding variations in conscious-awareness of intrapersonal feedback in piano playing (e.g. Damasio, 2000).

Feedback in one-to-one lessons involves interpersonal feedback between teacher and student as well as intrapersonal feedback from the sensory system. Pedagogical studies suggest that instrumental and vocal learning and teaching often follow a master-apprenticeship model of transferring learning. This model is dominated by teacher verbal behaviour in lessons, but minimal student talk accompanied by student modelling of teacher playing (Hallam, 1998; Jørgensen, 2010). The model may be contrasted with a shared learning and teaching experience in an environment which focuses on the development of independent and autonomous student learning (Creech & Gaunt, 2012).

Interaction between teachers and students in instrumental learning and teaching tends to be circular (Burwell, 2010). Students rely on teachers to develop their independent and autonomous learning style (Gaunt, 2009), while teachers expect their students to be more independent and autonomous (Gaunt, 2007), even though teachers do not necessarily address this formally in their teaching (Gaunt, 2007). However, it has been suggested that technology can promote transformative learning, leading towards independent learning, through the application of assistive software programmes for instrumental and vocal learning (Creech & Gaunt, 2012).

Literature indicates that the majority of HE instrumental and vocal teachers do not tend to use technology in their lessons. This is due either to logistical issues or possibly to the bureaucracy required when teachers attempt to access technology in their institutions (Gaunt, 2007). Nonetheless, some teachers may encourage their students to use technology, such as audio and/or video recording for self-study practice away from the lesson, while a few teachers are reported as having used technology to listen back to recorded practice behaviours of their students within their lessons (Gaunt, 2007). Arguably, if instrumental or vocal teachers in HE were able to resolve the logistical issues related to technology use for their lessons so that teacher and student can have a hands-on and positive experience with assistive technology, the reported benefits of technology-mediated feedback would be more readily accessible to a greater number of students.

The number of research studies in higher music education has increased in the last decade in particular (see Jørgensen, 2014, for an overview), especially in the UK and Australia (Bryant, 2004; Burwell, 2010; Gaunt, 2007, 2009, 2011). Most of the studies have focused mainly on teacher or student perspectives, or on observed interactions between teachers and students in instrumental and vocal learning. Apart from a few studies in clarinet (Burwell, 2010) and piano (Bryant, 2004) which involve context specific features of learning and teaching, studies that focus solely on one instrument are less represented; similarly, there are few studies into the nature of feedback in advanced learning of specific instruments. Premised on this evidence, it can be argued that psychological and pedagogical understanding of HE learning and teaching of a specific instrument, particularly piano learning, remains under-researched.

Within the literature on interpersonal feedback in instrumental and vocal lessons, most research studies have focused on general feedback such as positive or negative aspects and on the quantity of general feedback available in terms of frequency, rather than on the quality of specific feedback. Interpersonal feedback is present in one-to-one instrumental and vocal tuition in the forms of verbal and non-verbal behaviours including feedback (as summarized in Table 4.2 in Chapter 4). These types of behaviours are commonly linked to particular musical performance parameters which can be worked on in one-to-one lessons in order to enhance student learning and performance for the selected interpretative or technical aspects when technology is applied (see Table 4.4in Chapter 4). However, what is still unclear and so needs to be understood and examined is: first, whether the nature of verbal and non-verbal behaviours, including feedback which was identified in previous studies, can be observed and applied in a piano learning studio with the use of technology; second, in what ways the nature and patterning of feedback enhances learning in the one-to-one piano studio when using technology-mediated feedback, and how to optimise this; and third, whether the use of technology-mediated feedback can enhance student learning and performance, and if so, for which musical performance parameters.

Additional feedback, such as in the form of visual feedback, has been shown to enhance learning. The benefits of using technology in advanced level individual learning were reported in several experimental studies on instrumental and vocal learning. Some of these studies have researched the application of RTVF in the singing studio with advanced vocal learners in the UK (Welch et al., 2005), the use of RTVF in imitating expressive tapping or percussion performance (Brandmeyer, 2006; Sadakata et al., 2008), and the use of computer feedback when communicating emotions in guitar performances (Juslin et al., 2006). Video recording was also used in two HE studies: first, in investigating the perspectives of music students on the role of video and audio recording in learning for a large number of instrumental and vocal students (Daniel, 2001); and second, in examining the perspectives of teachers on watching their own videoed lessons alongside one of their peer teachers in exploring reflections on their teaching practices (Carey & Grant, 2015a). Apart from Welch et al. (2005), previous studies do not appear to have applied technology-mediated feedback in a real world context, namely, in a one-to-one instrumental or vocal studio, where teacher and student set their learning priorities and performance goals whilst using the technology in their lessons.

The number of investigations that have examined piano learning, either as a first or second instrument, and the use of technology at HE level remains small (Benson, 1998; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010). However, the effect of the use of technology has been researched so as to evaluate the use of instructional media resources in piano group lessons (Benson, 1998), and student perspectives on the prospective use of MIDI feedback in piano learning (Riley, 2005), the use of CCPP in their self-study learning (Tomita & Barber, 2008), and the use of audio recording and playing back in piano learning (Zhukov, 2010). However, no study seems to have examined the use of technology in piano learning in a live learning context, with a teacher working alongside a student in their lessons. In addition, no study has been conducted on the use of technology, particularly the application of additional feedback such as visual or auditory feedback, in an advanced-level piano learning studio.

From this earlier research into piano learning and use of technology arise two main issues in the methodology used in these studies. The first is that the studies were conducted outside the context of individual tuition such as self-study (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010). Second, previous studies were based on the perspectives of piano students in evaluating technology, for instance, MIDI feedback (Riley, 2005), video recording (Daniel, 2001), audio recording (Zhukov, 2010), and CCPP (Tomita & Barber, 2008) rather than on observation and interviews which aimed to address what students were experiencing in learning with technology within a piano lesson alongside their teachers.

Overall, there is evidence that the application of technology in the context of a piano learning studio is under-researched, which renders such a study necessary, and particularly for HE level learners, on whom less research has been conducted. Furthermore, in the light of the literature reviewed in Chapters 2, 3 and 4, it is argued that no study so far has developed a distinctive methodology to explore the application of technology-mediated feedback in an advanced level piano studio, specifically in terms of tracking such additional feedback as visual or auditory feedback, in real time and post-hoc. In-depth applied research on piano learning at HE level continues to be under-researched in the music research field. Although technology is held to be a transformative tool in instrumental and vocal learning based on experimental studies, no previous research has explored the actual application of technology in piano learning and teaching at HE level. Consequently, the current study aims to explore and understand the use of technology-mediated feedback as a prospective pedagogical tool in piano learning; it also aims to examine student and teacher perspectives of their real experience in making sense, engaging with, and using additional technology within their one-to-one lessons according to their chosen learning priorities and performance goals.

The design of an appropriate methodology for this doctoral research study is discussed in the next sections; the research was designed in order to investigate the following research questions:

1. What is the nature of feedback in higher education piano learning and teaching when technology-mediated feedback is applied?

2. How is technology-mediated feedback applied in higher education piano learning and teaching?

3. Does the application of technology-mediated feedback enhance higher education piano learning and teaching, and improve student performance in piano lessons?

5.3 An exploratory action case study approach

This study adopted an exploratory action case study approach. An action case approach (Braa, 1995; Braa & Vidgen, 1999) is a hybrid research approach which encompasses elements of case study (Stake, 1995; Yin, 2014) and action research (Kemmis, 1993) approaches. It is argued that an exploratory action case study approach is adopted in this current research study. The study can be seen as an *intervention* in a *case*, the intervention being the application of technology-mediated feedback in a case of HE level piano learning and teaching. The argument that a hybrid research approach is appropriate for this study is discussed below.

A case study approach offers diverse ways to research a phenomenon (Stake, 1995; Yin, 2014). According to Stake (1995), a case study approach can be intrinsic, collective, or even instrumental. Yin (2014) argues that case study approaches have three dimensions: first, they can be single or multiple; second, they can be holistic or embedded; and third, case study approaches can be exploratory, descriptive, or explanatory. According to Yin (2014, p. 16):

> A case study is an empirical inquiry that investigates a contemporary phenomenon (the “case”) in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident.

The current doctoral study has characteristics of the case study approach defined by Yin (2014). The case in this study is one-to-one piano learning and teaching in HE mediated by the application of assistive technology regulated by the researcher. Three pairs of teachers and students in one-to-one piano lessons were chosen to participate in this study, which took place over a period of two weeks per pair. According to the classifications proposed by Yin (2014), the current study falls into a single, holistic and exploratory case study approach of three HE teacher and student pairs in piano learning and teaching. According to the case study concept proposed by Stake (1995), this present case study is both collective, because it investigates more than one teacher and student pair, and instrumental because it tries to understand something other than a particular case such as the application of technology-mediated feedback in HE piano learning. The closest methodological approach related to the current study is that of the case study, as the purpose of a case study is ‘to identify the research questions or procedures to be used in a subsequent research study, which might or might not be a case study’ (Yin, 2014, p. 238). The current study is not a descriptive case study as its purpose is not ‘to describe a phenomenon (the “case”) in its real-world context’ (Yin, 2014, p. 238), something which has already been achieved in HE piano learning study conducted by Bryant (2004). Nor is the current study an explanatory case study as it does not aim ‘to develop an explanation about the occurrences in a case’ (Yin, 2014, p. 238) by investigating observed events in one-to-one HE level piano lessons. Rather, the current study relates to the use of assistive technology in three HE level one-to-one piano lessons; one purpose of this study is to provide a basis upon which further research can be based. However, given that this study encompasses an in-context intervention of technology, it may be argued that the case study approach label is not entirely applicable to this study. The second methodological aspect of this study, the action research element, is set out below.

The application of technology and participation of myself as facilitator of technology in this study encompasses a component of action research such that the study could be defined as ‘a small-scale intervention in the functioning of real world and a close examination of the effects of such an intervention’ (Cohen & Manion, 1994, p. 186). The action research approach label, however, is not fully appropriate here as the study does not seek ‘to change the situation being researched’ (Scott & Morrison, 2006, p. 4) which has already been done in a previous study (Welch et al., 2005). In addition, rather than being conducted by a researcher as a participant observer and facilitator of technology, action research is usually conducted ‘by practitioners into their own practices’, in a real learning and teaching setting in order to improve '(a) their own social or educational practices; (b) their understanding of these practices; and (c) the situations in which the practices are carried out’ (Kemmis, 1993, p. 177). The research design of this current study was not carried out by practitioners on their own practices as suggested by Kemmis (1993), but by a researcher alongside teachers and students; for those participating in this study, the aim was not necessarily to improve the practices of teachers and students per se, but rather, to explore the application of technology in their lessons.

Similarly, the study is neither experimental nor is it ‘ex post facto’ research (Cohen et al., 2013, p. 303). Experimental studies usually involve a research design where ‘investigators deliberately control and manipulate the conditions in which they are interested and measure the difference that it makes’ (Cohen et al., 2013, p. 312). The control of experiments can vary from very stringent to more flexible with the purpose of examining ‘possible cause-and-effect relationships’ between variables (Cohen et al., 2013, p. 303) which has already been conducted in several previous studies (Brandmeyer 2006; Sadakata et al., 2008; Welch, 1983, 1985a, 1985b).

In the current study, there was no attempt to examine cause and effect relationships between variables by using an intervention to examine the effect of one variable on another, for example the effect of dynamics on timing. On the contrary, in this study, the application of the technology aimed to explore the use of technology in HE piano lessons in order to examine which musical performance parameters would emerge from it. This application of technology acknowledged the individual differences of either the student or teacher, and the repertoire worked on in this specific context. In addition, to conduct an experiment would have necessitated choosing one or two musical performance parameters from a list of many in order to for those particular parameters to be investigated in piano lessons; this is somewhat different from exploring the musical performance parameters which could emerge from the piano lessons while technology-mediated feedback is being applied in HE piano learning.

An action case approach was developed by Braa (1995) in the field of information systems and contained 'elements of action research (small-scale intervention is intended), case study (an understanding of the research question in an organizational context is sought), and field experiment (an experimental approach)' (Braa, 1995, p. 2). Several years later, Braa and Vidgen (1999, p. 44) stated that an action case approach reflects 'a method that is a hybrid of action research (intervention) and soft case study (interpretation)'. The characteristics of action case study approach as stated by Braa and Vidgen (1999) seems to be more applicable to this study than the one proposed by Braa (1995). This is because this study combines case study and action research approaches but does not include elements of an experimental approach. However, it is argued that action case study is the closest form of research approach for this study since it involves the following features: 'projects with short duration[,] interventions happening in real-time[, and] the inclusion of case study elements in order to support understanding of the domain' (Braa, 1995, p. 31). In addition, Braa and Vidgen (1999, p. 44) reported that an 'action case approach can be adopted by new researchers, such as doctoral students, who wish to gain experience of in-context research on a small-scale and structured intervention'.

Therefore, the definitions of a case study approach proposed by Yin (2014) and Stake (1995) do not exactly meet the definitional needs of this current study, even though the current study involved an in-context investigation. Likewise, the action research approach (Kemmis, 1993) does not wholly represent this study, even thought there was development of a methodology when conducting the pilot studies, and an intervention of technology in a specific context. It thus seems more appropriate to categorise this current study as an exploratory action case study approach (Braa & Vidgen, 1999), seeing that it investigated the application of technology-mediated feedback in HE level piano studio. Acknowledging the challenges in finding a methodology which best described the one adopted in this study, it is therefore argued that an exploratory action case study approach was adopted since this combines elements of the case study and action research approaches as set out above.

5.4 Observations, technology-generated data and interviews

Several different data collection approaches have been adopted in research studies in instrumental and vocal learning and teaching (Bryant, 2004; Burwell, 2010; Carey et al., 2013; Carey & Grant, 2015b; Creech, 2012; Gaunt, 2007, 2009). In most of these studies, data were collected through observation (Benson & Fung, 2005; Burwell, 2010; Kostka, 1984; Siebenaler, 1997; Speer, 1994) or semi-structured interviews (Burwell, 2010; Creech, 2012; Gaunt, 2007, 2009) and analysed either qualitatively or quantitatively. Qualitative data addressed different categories of teacher and student behaviours while quantitative data addressed the length of time spent or proportion of each behavioural category in a unit of analysis, e.g. one lesson, rehearsal frame or excerpts of lessons.

The current study uses two of the main types of data collection recommended for case study research (Stake, 1995; Yin, 2014): observation and interviews. These are supplemented by additional technology-generated MIDI data. Observation, which provides opportunities to watch what participants actually do and talk about instead of hearing about, captures 'real life' environments (Robson, 2002). Interviews bring interviewee perspectives to light by elucidating aspects which are observed or not by the researcher (Stake, 1995). According to Stake (1995, p. 66), although observation and interviews are both used 'to find out what happened' in the fieldwork, in observation '[w]hat is observed usually is not controlled by the researchers'; in interviews ‘the interviewee may tell [researchers] quite a bit about the interviewee but so often not what [researchers] need to know about what the interviewee has observed’.

The major advantage of observation is its ‘directness’ by watching ‘what [people] do and listen to what they say’ (Robson, 2002, p. 310). However, one major disadvantage of observation is that it involves ‘the extent to which an observer affects the situation under observation’ (Robson, 2002, p. 311). The role of the researcher needs to be well-defined before embarking upon the fieldwork, in order to minimise any issues that may arise from the methodology chosen. The advantages of interviews include its ‘flexible and adaptable way’ by ‘asking people directly about what is going on’ when researchers look for answering their research questions, and ‘the potential of providing rich and highly illuminating material’(Robson, 2002, pp. 272-273). However, one disadvantage of interviews is that depends on ‘considerable skill and experience in the interviewer’ (Robson, 2002, p. 273). Although observation and interviews are both time-consuming processes, there are advantages in conducting a triangulation of data collection and analyses in order to confront ‘discrepancies between what people say that they have done […] and what they actually did’ (Robson, 2002, p. 310).

The current research draws on the observation method of data collection and analyses because of the richness of what happens in the lessons when technology-mediated feedback is applied. Technology-generated MIDI data were also collected in the lessons as an alternative type of data called *‘electronic process data’* (Bergmann & Meier, 2004, p. 244, original emphases). MIDI data are related to the term electronic process data since these types of data refer ‘to all data that are generated in the course of computer-assisted communication processes and work activities’, and provide a documentation of ‘what is happening on the computer screen, and can be repeatedly viewed for the purposes of analysis’ (Bergmann & Meier, 2004, pp. 244-245). In addition, interview data were also collected and analysed as a secondary source to better understand the video observations which reveal the pedagogical feedback processes associated with MIDI data. Drawing on these three complementary sources enables fuller and more nuanced analyses of piano learning and teaching to be obtained.

5.5 Pilot case studies

This section addresses the pilot studies conducted before the main research design was finalized and fieldwork data collected (Figure 5.1). Six pilot studies were conducted at different stages, between May 2012 and July 2013 of this doctoral study in order to define the research design for the main fieldwork study and to understand the role of the researcher in this study. The development of the methodology is shown in Table 5.1. Pilot study 1 was the only one which was conducted in its natural setting and without the application of technology-mediated feedback. Following the findings which resulted from pilot study 1, the research design was developed and explored in different ways from pilot studies 2 to 5. The final research design was tested in pilot study 6 and also replicated in the main study which constituted two phases: the initial pool of participants, and case studies A, B, and C in HE piano learning and teaching.

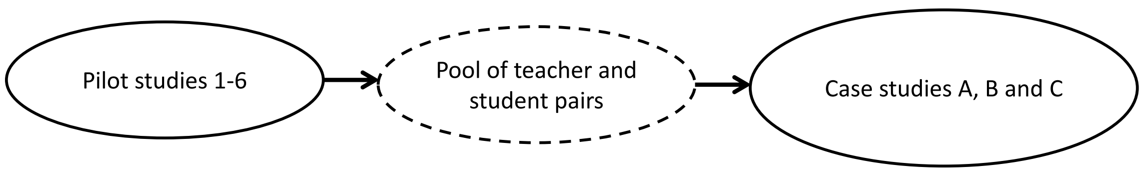


Figure 5.1 Scheme of the current study from the six pilot studies to the three case studies A, B and C

Table 5.1 Development of methodology for the current study according to successive pilot studies

Pilot study	**1**	**2**	**3**	**4**	**5**	**6**
Date	May (2012)	Feb (2013)	Mar (2013)	Mar (2013)	Jul (2013)	Jul (2013)
Participants	One HE teacher and two piano students	HE piano student, and the researcher	researcher	Master level piano student, and the researcher	Teacher, an advanced level piano student, and the researcher	Teacher, an advanced level piano student, and the researcher
Gender of participants	Teacher (female), and two students (female)	Student (male), and researcher (female)	Researcher (female)	Student (female), researcher (female)	Teacher (female), student (male), and researcher (female)	Teacher (female), student (male), and researcher (female)
Repertoire	Four piano pieces (first-year student) and a Romantic concerto (second-year two student)	One asked piece by Chopin and one chosen piece by Schumann	One sight-reading piece by Scriabin	One sight-reading piece by Scriabin and one chosen piece by Schumann	Memorized chosen piece by Chopin	Memorized chosen piece by Schumann
Role of researcher	Observer	Participant-observer	Participant (biased)	Participant-observer	Participant-observer	Participant-observer
Technology	No	Yes				
Type of technology	N/A	Digital stage piano (Yamaha CP300) connected to a laptop DELL computer running a digital work station software (Cockos' Reaper) via a MIDI interface				
Number of sessions	1	1	1	1	1	2
Data collection	Video observation and ranking questionnaires	Video observation	Video observation	Video observation	Video observation and interviews	Video observation and interviews
Data analysis	Thematic analysis (NVivo9)	Thematic analysis (NVivo10)	Thematic analysis (NVivo10)	Thematic analysis (NVivo10)	Thematic analysis (NVivo10)	Thematic analysis (NVivo10)

The first pilot study (Hamond, 2013b, 2013d) was conducted in order to investigate the nature of feedback in an HE piano studio and the views of teachers and their students on the most difficult aspects in piano learning and teaching. The participants were one piano teacher and two of their principal study pianists, from the first and second year of study respectively, in a music department of a university in the UK. Data collection involved video observation of one piano lesson per student with the same teacher. The first-year piano student played four different short pieces. The second-year piano student played two movements of a romantic concerto. Videoing was followed by the completion of a ranking questionnaire on piano-learning priorities completed separately by both students and the teacher. The 7-point Likert scale ranking questionnaire was completed on the following musical performance parameters for piano learning: timing, articulation, fingering, phrasing, rhythmic accuracy, melodic accuracy, dynamics, rubato, pedalling, tone quality, musical structure, emotional expression, interpretation, style, and overall flow (see Appendix 1). Data analysis was conducted using CAQDA software. Thematic analysis was conducted according to the themes identified in the synthesis of verbal and non-verbal feedback described in Chapter 4 (see Table 4.2 in Chapter 4), musical performance parameters related to these themes (see Table 4.1 in Chapter 4), and emerging coding themes.

In the first pilot study, the findings from video observations suggest that the nature of feedback in HE level piano lessons was verbal and non-verbal (Hamond, 2013b, 2013d). Types of teacher verbal feedback included providing information, giving directions, asking questions, and giving general feedback both positive and negative. Types of teacher non-verbal feedback encompassed not only playing but also conducting, singing, making a rhythmic sound such as ta-ta-ta, making a “sh” sound, and tapping the pulse or snapping the fingers alongside student performance (Hamond, 2013d). In addition, particular musical performance parameters seemed to be related to either verbal or non-verbal feedback (Hamond, 2013b). Overall, teacher verbal behaviours were delivered mainly on four musical performance parameters, namely timing, music structure, dynamics, and technique (Hamond, 2013b), which seemed to be related to different categories of verbal behaviours for example, providing information, giving direction, asking questions (Hamond, 2013b, 2013d). Examples of types of teacher behaviours, including feedback, linked to particular musical performance parameters such as musical structure, timing, interpretation, technique, and dynamics, are illustrated in Table 5.2.

Table 5.2 Examples of teacher verbal behaviours including feedback regarding musical performance parameters of student performance in pilot study 1 for first- and second-year lessons (adapted from Hamond, 2013b)

Musical performance parameters	Teacher verbal feedback	Examples for the first- and second-year student lessons
Dynamics	Giving directions	"warmer", "louder", "pianissimo" (second-year student lesson)
Dynamics	Providing information	I think in Debussy if you can be utterly precise with your dynamic marks, it really makes a difference, maybe more with Debussy than with any other composer. (first-year student lesson)
Interpretation	Providing information	It might take longer before they [the listeners] feel that they know what you want to do with this piece. (first-year student lesson)
Musical structure	Asking questions	How are we going to get a relationship between this and this? (first-year student lesson)
Technique	Giving directions	Do that beautifully three times... Then this, then this and then this. You do that every time you practice and then within a few days you'll wonder what the problem was. (second-year student lesson)
		I'd say the faster you can do it tidily, the better. (first-year student lesson)
Timing	Asking questions	Could you tell me where the discrepancies are with tempo? (first-year student lesson)
Timing	Providing information	...We need to look at the tempo of that agrees with this. (second-year student lesson)

Findings from the ranking questionnaire (Hamond, 2013b, 2013d) showed discrepancies between teacher and students perspectives on student learning priorities. Findings suggest that the application of technology in the piano studio might reduce these differences between participant views and the observed data (Hamond, 2013b, 2013d). Differences between teacher and student perspectives of piano learning priorities are shown in Table 5.3 which draws on a ranking questionnaire of fifteen musical performance parameters. In Table 5.3, the most difficult musical performance parameters to be learnt or taught, which were ranked 5 or above, are demonstrated in parentheses (Hamond, 2013b).

Table 5.3 Differences between perspectives of teacher and their students on student learning priorities (adapted from Hamond, 2013b)

<table>
<tr><th colspan="2">Perspectives on piano-learning priorities - students versus teacher</th></tr>
<tr><th>First-year student individual perspectives</th><th>Teacher views on the first-year student</th></tr>
<tr><td>Fingering (7)</td><td rowspan="2">Phrasing (5)</td></tr>
<tr><td>Pedalling (6)</td></tr>
<tr><td>Dynamics (5)</td><td rowspan="3">Rubato (5)</td></tr>
<tr><td>Tone quality (5)</td></tr>
<tr><td>Style (5)</td></tr>
<tr><th>Second-year student individual perspectives</th><th>Teacher views on the second-year student</th></tr>
<tr><td rowspan="4">Dynamics (5)</td><td>Timing (5)</td></tr>
<tr><td>Articulation (5)</td></tr>
<tr><td>Fingering (5)</td></tr>
<tr><td>Musical Structure (5)</td></tr>
</table>

Key: The ranked scores are demonstrated in parentheses, where 7 is the most difficult musical performance parameter to be learnt or taught.

Prior to, and between the subsequent pilot studies, I explored the use of technology-mediated feedback. This was to gain experience in dealing with the technology when conducting the subsequent pilot studies. The five exploratory pilot studies were undertaken in order to investigate more systematically the use of technology in a piano studio either with a piano student, or with both a teacher and a student. Another pilot study was conducted with myself as the only participant in a self-study. Piano teacher and student pairs who participated in these five pilot studies were invited to have their videoed piano sessions and interviews in the Music Technology Suite, University College London—Institute of Education (UCL-IOE), where the data collection was conducted from February to July 2013. The equipment involved in all following pilot studies was a digital stage piano connected to a laptop computer running DAW software via a MIDI interface, and an additional computer screen.

The second and fourth pilot studies were each conducted as a practice session (rather than lesson) with two advanced level piano students alongside myself; I adopted the role of facilitator by mediating the technology. These two pilot studies were undertaken in order to examine whether advanced-level piano students at undergraduate and postgraduate levels, were able to make sense of the visualization generated by the technology applied in order to improve their performances. Findings of these pilot studies suggested that the participants could relate the visualization to particular musical performance parameters which were observed through the piano video session for melodic accuracy, articulation, rhythmic accuracy, pedalling, dynamics, and timing or tempo (Hamond, 2013a, 2013c). During the practice session, the postgraduate level piano student stated the value of using of the technology in piano lessons, saying that “this could help us to know more what exactly we are doing” and “it could be useful to watch it, and not to talk about it” (Hamond, 2013c).

The third preliminary pilot study with technology was conducted with myself for the purposes of self-study when sight-reading a short piece by Scriabin in one practice session. As the researcher embarking on a self-study, I felt biased because of my prior knowledge of the system, and my attachment to my research. Although I was aware of the musical performance parameters which could be improved in my playing through the visual feedback I was likely to respond to, I was not in my best shape for piano playing at that time which contributed to the biases. However, this third pilot study was decisive because it assisted me in defining the role of the researcher as a facilitator when operating the technology rather than adopting the double role of teacher and researcher.

Finally, the fifth and sixth pilot studies were undertaken with a more structured research design, by adopting video observations and interviews with a piano student and teacher as data sources, accompanied by the researcher as the facilitator of the technology. The aims of these two pilot studies were: first, to investigate more systematically the pedagogical use of technology in a piano studio; and second, to understand teacher and student perceptions of the use of technology in a piano studio.

The equipment used in these two final pilot studies was consistent with the previous four pilot studies. The use of technology-mediated feedback was exploratory in order to foster improved performance of a chosen piece for each pilot study. In the fifth pilot study, the chosen piece was an étude by Chopin, while in the sixth pilot study it was a piece by Schumann. The difference in the research design between these two last pilot studies related to the number of lessons observed and the number of interviews: one interview for the fifth pilot study and two for the sixth pilot study. The lessons were videoed and participants interviewed afterwards.

The observed data suggested that the participants seemed to be establishing a relationship between what they heard and what they saw on the computer screen. The interview data showed teacher and student views of the use of the technology in the piano lesson and highlighted the musical performance parameters which were worked on. Preliminary findings from these two pilot studies seemed to have: first, promoted a similar perspective between teacher and student; second, made the teacher and student identify and agree on learning priorities; and third, had an impact on student learning and teacher pedagogical approach (Hamond, 2014a, 2014b).

5.6 Implications of pilot case studies for the main study

The succession of exploratory pilot studies was essential to the research design of the main study. The research design adopted followed the pattern of the sixth pilot study, which involved two piano lessons. The research design for the main study used the case study protocol for observation and interview data collection described in Section 5.5. The protocol for the main research study provided an information leaflet on the project, the consent form to be signed by the participants, the protocol script for the observation of the piano lessons (see Appendix 2), and the protocol for conducting the semi-structured interviews (see Appendix 3).

After conducting the preliminary pilot studies, my role as the researcher became much clearer for the main study, that is, the exploratory action case study approach. My role was as a participant-observer who facilitates the piano lessons by mediating the technology for the participants. My role as facilitator involved not only opening an electronic project, saving the project, playing it back, playing it back slower, scrolling up and down the screen, zooming in and out, showing key velocity numbers, but also, for example, commenting on the possibilities of the use of technology such as recording, playing back and playing back slower. Importantly, my role was not to deliver feedback on student performances; this was left to the teacher as commonly found in a traditional one-to-one piano learning and teaching setting.

The purpose of this methodological approach was to provide a neutral environment between myself and the teacher and student pair for each case study as neither the teacher nor the student had previous experience of this type of technology. Furthermore, I did not know in advance which music pieces the participants would choose. The teacher and student pair would contribute to the piano lessons with their experience of working on a selected piano piece while I would contribute to the piano lessons from my previous experience and expertise in the use of technology-mediated feedback.

Limitations of the research design of the last five exploratory pilot studies were fivefold. First, the use of a digital piano instead of an acoustic piano for advanced level piano performances meant that students needed to adjust to an instrument which they were unaccustomed to using in their conventional piano lessons. Second, the interface of the DAW software which was generated in real-time while recording the performance-related data was in black and grey. This was in contrast to the coloured interface which was generated post-hoc while playing back the performance. Participants expressed a preference for using the coloured mode rather than the black and white mode as it showed more detailed visual information about the performance. Third, the application of the technology for complex piano pieces led to complex visualizations. This meant that in a two-week period, participants would gain greater benefit from the use of technology when performing technically simple pieces rather than complex pieces, as it was challenging for them to understand the complex visualizations which accompanied the more complex pieces. Fourth, there were technical problems which occurred when using technology such as the software "Not Responding" which meant that the software was running slower because of a temporary problem in the program. Other technical issues occurred, for example an accidental recording which meant to record data over a pre-recorded performance-related data, and the screen displaying other various information without setting up, such as key velocity numbers which appeared automatically when the recorded performance was being played back. Fifth, despite the prior training I had undertaken, my knowledge of dealing with the technology was still limited. This meant that my role as facilitator faced limitations when I was asked by participants to operate the technology in a way I had not practised or explored previously. DAW software adopted in this study offered many tools which required me to develop my skills in using the system, dependent on operating selected functions to assure consistency of the application of the system. Although these limitations were acknowledged, they were not considered major enough to impact the study negatively. Thus, my training with the technological system during these six pilot studies allowed me to prepare myself to explore its use further in the main fieldwork study.

5.7 Data collection

Data collection involved gathering three data sources: video observation, technology-generated MIDI data and interview. Data and method types of triangulation were used to achieve quality criteria in this study as suggested by (Guba, 1981; Shenton, 2004) (see Section 5.10). Video observation of six piano lessons, two for each of three teacher and student pairs, was conducted. I operated the technology-mediated feedback during these lessons. Semi-structured interviews were conducted with the participants separately after each lesson. Additional technology-generated MIDI data were also collected whilst recording the performance of participants' chosen pieces. The digital system consisted of a digital piano, MIDI interface, and DAW software such as the Cockos Reaper which offers 'a full multitrack audio and MIDI recording, editing, processing, mixing and mastering toolset' (taken from http://www.reaper.fm/).

5.7.1 Participants

Three teacher and student pairs in HE piano learning and teaching in Brazil were the main foci of this study, which examined the pedagogical use of technology-mediated feedback in HE piano studios. Data collection was conducted from an initial pool of eight piano student and teacher pairs. Three out of eight participant pairs were selected to be reported here since they best matched the original selection criteria to take part in the study. The process of data collection is discussed below.

To select participants, I used the 'snowball' strategy proposed by Flick (2009, p. 110), whereby I contacted new colleagues, such as piano teachers, in the UK and asked if they could put me in touch with their acquaintances in the field of piano pedagogy. The initial research design for the main study entailed collecting data in the UK. However, finding HE teachers and students in the UK willing to participate in this study was challenging. In response to the difficulty of finding participants for this study, the criteria of the study were amended with regard to the expertise level of participants in playing and memorization abilities. This amendment enabled me to find two non-HE level teacher and student pairs in the UK. In an attempt to find HE level participants, I then sought prospective participants in my home country of Brazil, where I found six teacher and student pairs, three of them at HE level. These participants were also selected through a snowball strategy. Thus, an initial pool of sixteen participants was formed, consisting of two teacher and student pairs in the UK and six such pairs in Brazil.

Data collection was conducted between late November 2013 and February 2014 in the UK and in Brazil. Data collection in the UK was held at the UCL Institute of Education; in Brazil, data collection was undertaken at an anonymous HE institution through a pedagogical project which allowed me to have access to their facilities. Data were thus collected from an initial pool of eight piano teacher and student pairs—two in the UK and six in Brazil—who had been working together for at least ten weeks working on a memorized piece at Grade 8 level (see Appendix 4). The sixteen participants did not receive any financial reward for taking part in the research project, but all were offered reimbursement for their transport expenses as stated in the information leaflet, and most took this reimbursement. The length of time the teacher and student pairs had worked together was greater than one term, for example ten weeks, which was requested on the information leaflet. The overall background of the eight pairs from the initial pool of participants who completed the minimum required number of two videoed lessons and two interviews is shown in Table 5.4.

Deciding to collect data in Brazil had advantages and disadvantages. One advantage was that the data could be collected in Portuguese, my mother tongue, transcribed in Portuguese and then translated into English. However, the financial investment needed to acquire the pieces of equipment such as digital cameras, tripods, and a voice recorder for the data collection, and other expenses involved in travelling to Brazil were also disadvantages.

The teacher and student pairs each had two piano lessons videoed by myself. The teachers and their students also participated in the semi-structured interviews separately after each lesson; the interviews were approximately forty-five minutes long. One prospective pair in the UK did not attend the minimum of two piano lessons followed by interviews, so this pair was discarded from the research project.

The aim in selecting participants was to have pairs of teachers and students at advanced piano level who fulfilled three criteria. As noted above, these initial criteria had to be modified in response to the challenge of finding participants, and in case participants dropped out of the research. Following data collection, however, it was possible to discard data from those pairs who did not fit the original criteria. This was as follows. First, the pair needed to have been working alongside each other in an HE institution, such as HE level teachers and their principal or second instrument piano students. Second, participants had to have been working together for at least one term (ten weeks) on a weekly one-to-one basis. Third, pairs should have been working on a memorized piano piece of their choice. While I had sought pairs who had been working together for at least ten weeks, it transpired that all the participants had been working together for over two years.

The first criterion, choosing HE level students and their teachers from the initial participant pool, was based on previous studies having suggested the benefits of using technology in this context. The second criterion, choosing pairs of teachers and students who had worked together on a regular weekly one-to-one basis for at least one term, was to ensure that the exploratory use of technology would not interfere with their relationships or commitment towards a defined goal such as student performance or taking examinations. The third criterion related to the notion that piano pieces should be memorized in order to evaluate the use of RTVF whilst the students were playing the piece. If the student had not memorized their chosen piece, it would have been more challenging to evaluate whether they were looking at the computer screen or the music score.

Table 5.4 Initial pool of participants for this study

Teacher and student pair	Country	Participants	Gender	Age range (years old)	Overall piano teaching experience (years)	Place the lesson is usually conducted	Piano teaching experience with this student (years)	Memorized piano piece
1	UK	Teacher	F	35-55	Below 15	Further education school	2	No
		Student	F	20-35				
2	UK	Teacher	F	35-55	Below 15	Private place	8	No
		Student	F	Below 20				
3	BR	Teacher	F	Above 55	Above 30	Private place	6	No
		Student	F	35-55				
4	BR	Teacher	M	35-55	Around 30	Private place	4	Yes
		Student	M	20-35				
5	BR	Teacher	M	35-55	Between 15 -30	Private place	3	No
		Student	M	20-35				
CASE STUDY A	**BR**	**Teacher**	**F**	**35-55**	**Between 15 -30**	**HE institution**	**2**	**Yes**
		Student	**M**	**20-35**				
CASE STUDY B	**BR**	**Teacher**	**F**	**35-55**	**Around 30**	**HE institution**	**5**	**Yes**
		Student	**F**	**20-35**				
CASE STUDY C	**BR**	**Teacher**	**M**	**35-55**	**Around 30**	**HE institution**	**3**	**Yes**
		Student	**M**	**20-35**				

Key: The last three teacher and student pairs in bold denote those who fell into the criteria of the study. These pairs were named case studies A, B, and C; this thesis will report them as such.

Ultimately, only three pairs of teachers and students at an HE level from Brazil fulfilled all these criteria. Pairs one to five did not fit the criteria for one or more of the following reasons. First, they were not working in an HE setting. Second, they were working in a group lesson instead of a one-to-one pair. Third, they were not working on a memorized piece. Finally, not all students had a regular weekly lesson. These teacher and student pairs could have been included in the research as participants, had the aim of this study been a broader understanding of technology in a piano studio.

The last three pairs of teachers and students in Table 5.4, namely case studies A, B and C, were chosen from the pool of eight as they matched the original criteria for this study. In accordance with principles of anonymity (see above), they were named case studies A, B and C. The background of the participants is described below.

5.7.2 Background of participants

The three case studies in this study involved higher education piano teachers and their students who had been working together on a regular weekly basis for at least two years. Case study A consisted of a teacher and second instrument piano student while case studies B and C consisted of a teacher and their first instrument piano students. Although all students had chosen a similar piece to work on in this study, namely, one movement of a classical sonata, student expertise varied from intermediate to advanced levels. This ability range was indicated by the pieces included in their repertoire as well as whether they were a first or second instrument piano student.

All teachers had long-term experience in teaching the piano, and had accumulated experience either in live performing or in CD recording. They also had previous experience of applying technology in their lessons. Teacher A had used videos of world-class pianists to demonstrate piano technique in lessons, while teachers B and C had experience of audio or video recording student performance in piano lessons using iPad or mobile phones. All three teachers had experience of audio or video recording their own practices as preparation for their live performances.

Students A and B, and to a lesser extent student C, had previous experience with technology such as playing a digital piano, and audio or video recording their own performances as a self-study aid. Students A and B also had experience in using DAW software, particularly Reaper by Cockos, for the purposes of recording, including editing, processing, mixing and mastering. In addition, the student in case study A reported having knowledge about music notation software programs, for example, Finale by Makemusic, and other software programs, including Virtual Studio by Microsoft, and Reason by Propellerhead. There seemed to be a common belief among teachers, especially A and B, that the students might have greater familiarity with and understanding of technology than the teachers themselves. Both teacher and student participants reported that in the context of a higher education piano learning and teaching environment, they had never experienced technology like that used in the current study, that is, the technology-mediated feedback through a DAW software programme.

Learning and teaching priorities were also reported in the interviews. Teachers and their respective students identified the most difficult aspects to be taught or learned in a piano studio. These perspectives were then compared. Although teacher and student pairs had worked together for more than two years, interview QDA showed that their learning and teaching priorities did not always converge. This is in line with the questionnaire findings in the first pilot study which ranked responses (Hamond, 2013b). Table 5.5 shows the differences between teacher and student perspectives on learning priorities.

Table 5.5 Teacher and student learning priorities across case studies

Learning priorities		
Case study	**Teacher views**	**Student views**
A	Teach student to listen to themself; technique; phrasing; motor control issues; touch/tone quality; sense of harmony and tonality.	Music style; playing musically.
B	Teach student to listen to themself; music style; sight-reading; survive during a performance (performance itself).	Memorization of movements; pedalling; phrasing.
C	Teach student to listen to themself; musical language; musical perception; culture; music style, sight-reading; and rhythmic accuracy.	Finished performance; rhythmic accuracy; phrasing; dynamics.

Although the perspectives of teachers and their own students did not match (see Table 5.5) teachers across the three case studies agreed on one aspect of learning needs: they found it important to teach their students to listen to themselves in order for their students to become more conscious of their performances. It is possible that the use of technology-mediated feedback in the piano studio can, therefore, decrease any gap between the student and teacher perspectives on learning and teaching, at least in relation to the lesson foci and performance goals. The set of materials used in this study for the data collection is described below.

5.7.3 Materials

The set of materials used in this study was tested in advance of each phase of data collection. The materials can be classified into two groups: first, materials used to apply technology-mediated feedback in piano lessons; and second, equipment used to collect data through video observation, technology-generated MIDI data, and interviews.

The materials used in the application of technology-mediated feedback in piano lessons are shown in Figure 5.2 alongside the positions of the participants. These materials encompassed: one digital piano, Yamaha Clavinova CVP-403; two MIDI cables, THE SSSNAKE SK366-3-BLK MIDI; one laptop computer, SONY VAIO running

Cockos Reaper DAW software with piano roll screen option via a MIDI interface, MIDISPORT 1X1 USB; one additional PC screen, LG FLATRON W1943SE, to be placed in front of the piano student; and one VGA cable to connect the laptop computer and the additional PC screen (see Figure 5.2).

The data collection in this study involved video data, technology-generated MIDI data and interview data. These additional materials which were used for data collection in the main study are shown in Figure 5.3. First, the video data collection involved the use of the following pieces of equipment: two digital cameras, SONY HDR-CX280E handy cam, plugged into the main socket to avoid the battery running out; two tripods for the digital cameras, and one voice recorder, a Zoom H1 Handy Portable Digital Recorder. Second, the collection of technology-generated MIDI data was intrinsic since it used the same materials involved in Figure 5.2. Finally, the interview data collection encompassed the use of one voice recorder, a Zoom H1 Handy Portable Digital Recorder. The music scores of the chosen pieces were brought by the participants without having been requested by the researcher, and were placed on a table closest to the teacher.

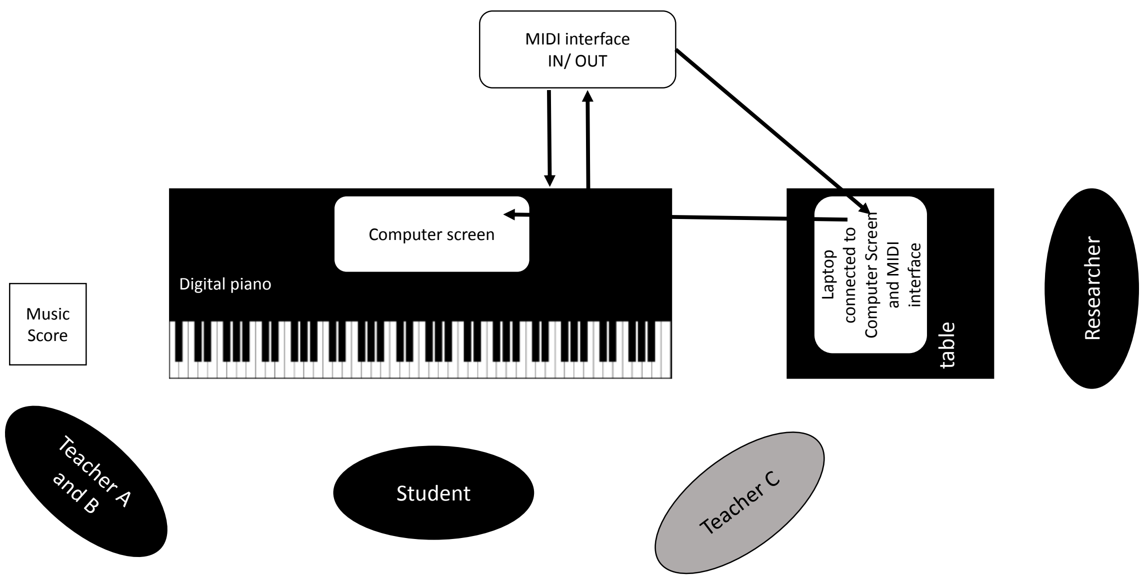


Figure 5.2 Top view of the positions of materials and participants

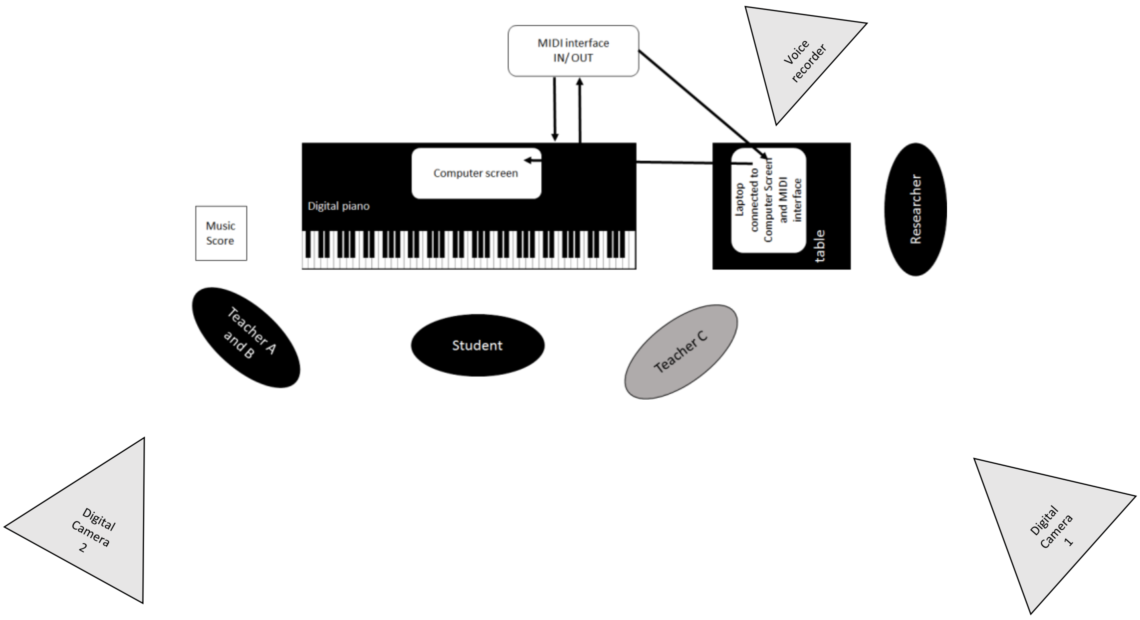


Figure 5.3 Top view of the positions of materials and participants including data collection equipment

Figure 5.2 shows an overhead view of the approximate positions of the materials and participants with two possible positions for the teacher: one to the right of the student and the other to the left of the student, and the pieces of equipment used in the piano lessons with application of technology-mediated feedback. Figure 5.3 shows an overhead view of the approximate position of the materials and participants, including the equipment which was used for data collection in the piano lessons such as a voice recorder, digital cameras, and the set up for the application of technology-mediated feedback.

There is a reason behind the decision to the use of a system involving a digital piano connected to a MIDI interface for this study. This system can provide both a recording and playing back of the performance-related data. Through this system, the keyboard and pedals activity of the teacher or student could be recorded and reproduced as faithfully as possible. The choice of DAW software was made because it can record not only audio data but also MIDI data generated through technology by teacher and student participants performing their chosen piano pieces. In addition, this set of materials appears user friendly and affordable; this would allow it to be adopted in a piano studio by HE teachers and even by their students themselves.

5.7.4 Video data, interview data, and MIDI data

Data collection in this study involved video, MIDI, and interview data. The video data were collected by recording two piano lessons of the regular teacher and student pairs working on a chosen memorized piano piece when technology was manipulated by myself. Two digital cameras were used to capture the interaction between participants, and what appeared on the additional computer screen on top of the digital piano. An additional audio voice recorder was placed on the table where I was using it during the lessons in order to assure the sound quality of the data and to make the transcription stage quicker for the videoed lessons.

The technology-generated MIDI data related to the performances that were recorded in the piano lessons, were also collected within the piano lessons. The MIDI data collection was derived from the intrinsic use of technology in piano lessons when the performance-related data was recorded using DAW software. MIDI data were saved on the laptop computer as projects in the DAW software for each case study and per piano lesson.

The interview data from the semi-structured interviews were collected through using a voice recorder which recorded individual self-reports of each participant separately. Table 5.6 shows details of each of the three case studies according to their respective chosen piano pieces, duration of videoed lessons and interviews held with teachers and students.

Table 5.6 Duration of each observed piano lesson and interview per case study

Teacher and student pairs	Chosen memorized piano piece	Piano student	Lesson 1 (duration)	Lesson 2 (duration)	Interview 1 (duration)	Interview 2 (duration)
Case study A	Mozart Piano Sonata No. 16 in C major, K. 545, second movement	Second instrument	1h13min	1h04min	T = 1h08min	T = 43min
					S = 1h04min	S = 43min
Case study B	Beethoven Piano Sonata No. 9 in E major, Op. 14, No. 1, first movement	Principal instrument	48 min	43min	T = 1h15min	T = 40min
					S = 36min	S = 29min
Case study C	Mozart Piano Sonata No. 2 in F major, K. 280, first movement	Principal instrument	48min	52min	T = 1h28min	T = 37min
					S = 53min	S = 32min

The data of case studies A, B and C were collected in a music room with facilities inside of a HE institution which was kept anonymous. My access to the HE institution was endorsed by a member of staff—a professor—who invited me to take part in their pedagogical project. This type of access of the researcher in the fieldwork was acknowledged by Flick (2009, p. 108). Taking part in a pedagogical project in this HE institution allowed me to be authorized by the administrative staff to conduct the research data collection, and to use a room and its facilities such as a digital piano, chairs, and tables.

The three case studies A, B and C were conducted within their usual institutional setting, but using a room other than the usual piano lesson venue. The case study piano lessons and interviews were conducted in the same place: a spacious music room where the available space was sufficient to accommodate the materials involved in this study as described. The chair of the teacher was positioned to the left of the student piano stool before the data collection started in order to prevent different video data collection angles. However, the position of the teacher in relation to the digital camera was different across the case studies. The position of teachers A and B were similar as they were seated to the left of the student. However, teacher C asked to sit to the right of the student, which might have obscured some non-verbal behaviours (see Figure 5.2for different teacher seating positions of teachers).

5.7.5 Ethical review

Ethical approval by the advisory committee of the Institute of Education was obtained. This covered all field work undertaken in this study: the pilot studies conducted in the UK and the main research study conducted in the UK and Brazil. Before the first pilot study, the anonymous HE institution in the UK also gave permission for research data collection in their setting and with their staff and students. Written consent to take part in the study was also received from teacher and student participants and the parents of one student participant under the age of eighteen. Using the British Educational Research Association (BERA, 2011) guidelines, participants were informed in advance about the nature of the current research study and the confidentiality of data pertaining to both the pilot and main research studies.

The participants in this study received an information sheet (see Appendix 4) about the aims, focus, and methods of this research study, and had the opportunity to ask questions. Moreover, the participants were asked to complete a consent form (see Appendix 5) to be submitted either before or on the day of the data collection for this current study. The participants in case studies A, B and C were adults. The participants were also informed that their participation was voluntary, and that they had the right to withdraw at any time, without giving any reason, and without penalty. The participants were also informed that both their individual identities and their affiliated institutions would be anonymised. The collected video, MIDI, and interview data were treated confidentially. The data were securely stored on my personal laptop which was password protected. Participants were informed that the findings of this study might be disseminated in conference presentation, publication in conference proceedings, and in the PhD thesis itself, but that personal details would be changed for these dissemination purposes.

5.8 Data analyses

In this exploratory action case study, data analysis involved a qualitative multi-method approach for video, MIDI, and interview data. Method and case triangulation was used to allow trustworthiness (Flick, von Kardoff, & Steinke, 2004; Guba, 1981; Shenton, 2004) in this study (see Section 5.10 for detail). The adoption of video Qualitative Data Analyses (QDA) provided an in-depth multi-dimensional approach to analyse the video data. The purpose of the video QDA involved understanding what was happening in terms of feedback and learning when participating HE teachers and their students had technology-mediated feedback applied in their piano lessons.

The video QDA encompassed analyses of the transcriptions of the video data. A CAQDA software package, QSR International NVivo10, was used for the thematic analysis within each case study and across case studies in two approaches. The first approach to video QDA was the thematic analysis of verbal behaviours, non-verbal behaviours including feedback, and musical performance parameters. The second approach to video QDA was the thematic analysis and pedagogical use of technology-mediated feedback (see Appendix 2 for video protocol). An additional and supplementary form of data analysis also derived from the video QDA was conducted: microstructure analysis of musical behaviour, for instance, the analysis of musical practice including listening back. The purpose of microstructure analysis of musical behaviour led to greater understanding of additional auditory feedback in piano lessons.

The MIDI QDA encompassed analyses of the technology-generated MIDI data in relation with the performance-related information in piano lessons. This form of data analysis was applied once MIDI data for the videoed lessons had been generated, applied, and collected. The purpose of MIDI QDA was to lead to a clearer understanding of additional visual feedback by showing a visualization of the activity of the keys and pedals on the digital piano.

The role of the interview QDA in this study complemented and supported findings which emerged from the in-depth video QDA of each participant piano lesson. The interview QDA encompassed analyses of the transcriptions of the interview data of each participant. Two semi-structured interviews were conducted with each participant. These interviews sought to obtain an overall picture of participant backgrounds, their experiences of piano learning and teaching, and the learning priorities identified by teachers and students when working on chosen pieces. The interviews also included questions about recent experiences of participants with technology-mediated feedback on their piano lessons (see Appendix 3 for interview protocol).

5.8.1 Transcription of video, music, and interview data

The piano lessons were both audio and video recorded, and the interviews were audio recorded. The audio MP3 files of the videoed piano lessons and semi-structured interviews were sent to a professional team for transcription, and returned as Word documents. Initially, the transcriptions of the video and interview audio MP3 files included only the verbalizations of the participants. The verbalizations of the participants in the video and interview sources were transcribed by a professional team, and checked twice. The professional team adopted an 'unfocused' approach which 'involves creating a record of 'what happened' within a given recording of speech or action' (Gibson & Brown, 2009, p. 113) where there was an emphasis on what was said, including actions such as playing, and not on how it was said by the participants. I conducted an additional transcription of non-verbal behaviours, which overlapped at times with verbal behaviours from the videoed lessons. In addition, I undertook transcription of the musical behaviour of the chosen music in each case study such as the musical excerpts which were played and listened back to. This later transcription used an online software program created by Demos & Chaffin (2009), originally designed to study your music practice (SYMP) (retrieved from http://musiclab.uconn.edu/introduction/).

Transcribing data has been seen as an important stage in the qualitative data analysis process. Although transcription is commonly conducted by the researcher rather than others, the immediacy of the transcription process by a third party is often held to be an advantage which should be taken into account when researchers are selecting the most appropriate method for research projects (Hennink & Weber, 2013). Although I transcribed the pilot study data, the decision was made to seek a professional team to undertake the transcriptions for the main study. There were two reasons for this: first, the data were collected at a late stage of the doctoral study when time was of the essence; and second, given that the transcription process is long and time consuming, professional transcription reduced further time delays.

The transcriptions were checked by myself several times for accuracy of transcription. I reviewed the transcriptions by listening to the audio recordings of the videoed lessons and interviews, and checking the audio recordings against the transcriptions of the verbalizations at the original speed as suggested by Easton, McComish, & Greenberg (2000). The transcriptions were reviewed several times at a slower speed by using a CAQDA software tool when more clarification of the speech was needed, since '[e]stablishing the trustworthiness of the transcripts would appear to be a fundamental component of rigor in qualitative research' (Poland, 1995, p. 1).

From the experience acquired in the pilot studies, a time interval—or a 'cooling off period' as suggested by Henley, Lau, & Spry (2016)—between research stages such as transcriptions of video and interview data and data analyses was needed. Since I was immersed in the intense experience of transcription, being away from the research data temporarily allowed for a holistic view of the data to be taken following a later return to the data. After the data had been transcribed, the multi-method data analysis approach was conducted as discussed below.

5.8.2 Computer-assisted qualitative data analysis (CAQDA)

Computer-assisted qualitative data analysis (CAQDA) software was used as a tool to assist in analysing the videoed lessons as the main source of data, and the interviews. The CAQDA software used was QSR International NVivo10; this aims to give the researcher 'a place to organize and manage' the video and interview data (taken from www.qsrinternational.com/what-is-nvivo). Advantages of the CAQDA software are to assist and support the researcher in several ways, such as to transcribe, edit and code data; it also includes the storage, searching and retrieval of data, analysis of frequencies, data display, and graphic mapping (Flick, 2009, p. 360).

The first stage, prior to conducting the data analysis with CAQDA, was to prepare the video sources to be imported. As mentioned above, each piano lesson was videoed using two digital cameras. These pairs of video shots of the same lesson were transferred onto the hard drive of an Apple computer where they were edited, and combined into a two-shot one video source in a MP4 output format (see Figure 5.4). This process used Apple Final Cut Pro editing software. Once every two-shot video source was in MP4 format, they were imported to the CAQDA software. Figure 5.4 shows a screenshot of a two-shot one video source from the main study data collection conducted in Brazil just after the piano lesson finished. In the top right is shown the video shot of the computer screen which was placed in front of the teacher and student pair and on the top of the digital piano. At the bottom is shown the video shot of the piano studio area where the participants interacted.

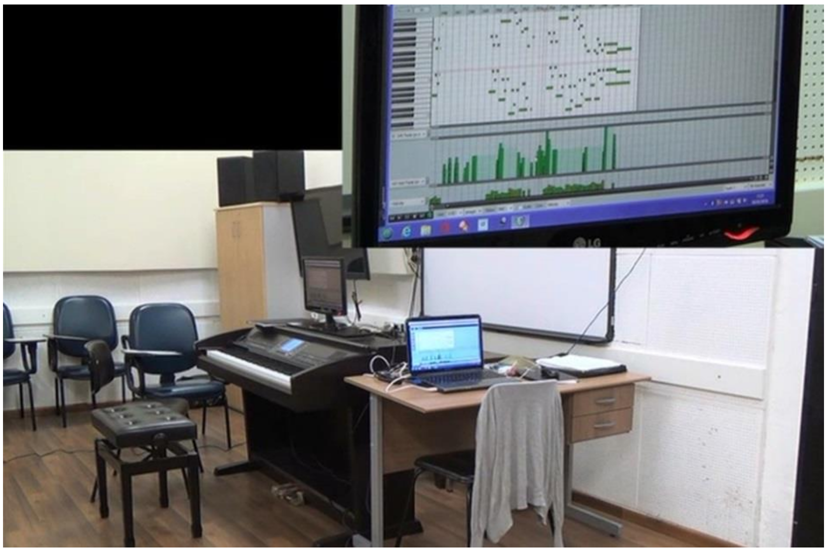


Figure 5.4 Example of a two-shot video source using CAQDA

The second stage of using CAQDA was to import and synchronize the transcription of the verbal behaviours with each corresponding two-shot video source. In addition, the transcription of the non-verbal behaviours was synchronized with each two-shot video source. Additional rows in the CAQDA navigation interface were added or cut according to the duration of the verbal and non-verbal behaviours which were observed when synchronized with the two-shot video source. The video sources could be coded when coming down to the content transcription rows, and to the timeline of the CAQDA software navigation view. This process will be reported in detail in Chapters 6 and 7 of video QDA for verbal and non-verbal feedback, and for technology-mediated feedback use, respectively. When expedient, use of the mute mode when running the video source through the CAQDA software was selected in order to have more clarity and focus on particular non-verbal behaviours. This stage of transcription was a continuous and cyclical process of reviewing the transcriptions for verbal and non-verbal behaviours. Once the transcriptions of verbal and non-verbal behaviours were reviewed and completed, the coding process started. An NVivo10 screen-shot of the CAQDA software interface with the transcript of a recorded lesson is shown in Appendix 6. Audio-recorded interview transcripts were similarly subject to the processes of importation and review.

5.8.3 Thematic analysis

Thematic analysis was undertaken in order to conduct the video and interview data analysis since it 'is a method for identifying, analysing and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail' (Braun & Clarke, 2008, p. 79). In a review of analytic approaches, Silverman (2010, p. 274) reported that thematic analyses encompass five stages: first, familiarization with the data; second, systematic coding of the data; third, searching for themes; fourth, reviewing the themes; fifth, refining the themes.

The advantages of conducting thematic analysis include three elements: flexibility of the method which means that it 'allows for a wide range of analytic options [and] means that the potential range of things that can be said about your data is broad' (Braun & Clarke, 2008, p.97); the ease of learning the method by non-experienced qualitative researchers; and the ease by which similarities and differences in the data set can be made (Braun & Clarke, 2008). However, the disadvantages include: the possibility of faulty data analysis; unconvincing analysis; and a possible discrepancy between theory and analysis (Braun & Clarke, 2008). Given these advantages and disadvantages, thematic analysis seemed to be the most appropriate analytic approach for this study, one main reason being that I am a non-experienced researcher in terms of conducting an exploratory action case-study research project based on video observations and semi-structure interviews. The impact of the disadvantages is diminished in a study when there is consistency in the analysis process (Braun & Clarke, 2008); this has been attempted in this study.

5.8.4 Video QDA: verbal and non-verbal feedback

The first approach to video data analysis focused on observed verbal and non-verbal feedback linked to the musical performance parameters worked on in the piano lessons. The video QDA for each piano lesson in each of the three case studies were conducted using CAQDA software. A two-shot video of each lesson provided the video data source used in the video data analyses. Thematic analyses were primarily used for coding observed verbal and non-verbal behaviours, and the musical performance parameters, which were worked in piano lessons when technology-mediated feedback was applied, in six videoed piano lessons (see Appendices 7, 8, and 9). Coding the analytical themes was done on transcript rows which were synchronized with the video source in the CAQDA software. The sub-categories of each of the three themes emerged from the synthesis of feedback on verbal and non-verbal feedback, and musical performance parameters in Table 4.2.

Through these data-collection procedures, an initial video QDA encompassed three main categories: verbal behaviours, non-verbal behaviours and musical performance parameters. The meta-category of participant verbal behaviours contained eleven observable sub-categories (see Appendix 7 for details). The meta-category of non-verbal behaviours contained seventeen sub-categories, each of which was observed in the videoed lessons (see Appendix 8 for details). The meta-category of musical performance parameters included a total of twenty-one sub-categories which were organized into three main categories: music, performance, and technology. Music-related parameters encompassed aspects related to the music score and musical structure of the piece. Performance-related parameters included aspects related to the execution of dynamics, tempo, articulation, and pedalling. Finally, technology-related parameters encompassed aspects of the technology system that was applied to lessons such as MIDI parameters, and digital piano (see Appendix 9 for details).

Although several studies have investigated teacher and student behaviours in instrumental and singing studios, there is little research establishing the link between observed musical performance parameters and verbal and non-verbal behaviours in piano lessons. In order to address this gap, I undertook a cross-tabulation between observed verbal and non-verbal behaviours and musical performance parameters to form a number of sub-categories. Cross-tabulation was conducted via a matrix coding query tool available in CAQDA software NVivo10 (see Appendix 10 for the generated matrices). This cross-tabulation enabled examination of the types of verbal and non-verbal feedback linked to musical performance parameters in piano learning when technology-mediated feedback was applied (see Chapter 6 for details).

Video QDA reports on the lesson context of each of the three case studies by focusing on three selected behaviours including feedback, namely: talk, playing, and feedback. Talk encompasses the sum of all verbal behaviours. Playing addresses only performance as non-verbal behaviour. Feedback encompasses the types of verbal and non-verbal feedback which were generated through the cross-tabulation between all sub-categories of verbal and non-verbal behaviours and musical performance parameters in the CAQDA software. Data were provided by all participants, and by each individual teacher and student participant separately, with regard to coverage of the time spent on talk, playing and feedback, and the frequency of references related to feedback in the two lessons.

Quantitative components of data analysis have been reported in previous research (Benson & Fung, 2005; Burwell, 2010; Welch et al., 2005). These studies used descriptive statistics to report frequencies, wordage, or time spent on each type of behaviour per participant. In this current study, the quantitative component generated through the use of CAQDA software is reported from two perspectives, the duration and frequency of events. Duration describes the percentage of time that each type of coded behaviour occurred within the total lesson time. Frequency describes the number of times that each type of coded behaviour was observed in each lesson. Although a large amount of quantitative data was generated, statistical analyses were not conducted due to the small number of observed piano lessons unlike the larger numbers obtained in previous studies (Creech, 2012). Video QDA for verbal and non-verbal feedback on musical performance parameters is discussed in Chapter 6.

5.8.5 Video QDA: technology-mediated feedback use

The second approach to video data analysis focused on the use of technology-mediated feedback. This analysis was conducted through coding video data on the timeline of the CAQDA software interface. The coding units were based on those used on the video QDA transcription rows, that is, verbal and non-verbal behaviours including feedback, and musical performance parameters. The previous video QDA also generated categories which were related to the technology-mediated feedback use over time and which were displayed as coding stripes on the timeline of the CAQDA software.

Groups of categories of technology-mediated feedback use were created throughout the timeline of the CAQDA software interface for each lesson per case study in order to show the visual distribution of technology use across the piano lessons. The groups of categories were related to the previous coding units from the video QDA as they incorporated shifts in behaviour for the application of technology by a request by the teacher or student, or at the suggestion of the researcher. These shifts included coding units such as my playing back or recording performance-related data, directions being given by the teacher, student or myself, and the teacher or student looking at the computer screen. Video QDA for technology-mediated feedback use is discussed in detail in Chapter 7.

5.8.6 Video QDA: additional auditory feedback across cases

The third approach to video QDA focused on the microstructure analysis of musical behaviour. Two types of musical behaviour were included: first, musical practice when the performance was played by the teacher or student; and second, listening back when the recorded performance-related data was played back. This analysis approach allowed the understanding of additional auditory feedback use in the piano lessons per case study.

The microstructure analysis of musical behaviour was conducted by using SYMP software (retrieved from http://musiclab.uconn.edu/introduction/). The SYMP software tool was originally designed to study the individual musical practice of one performer. However, in this study, SYMP software was adopted in order to investigate the auditory feedback available in a piano lesson, through musical practice and listening, during the application of technology-mediated feedback.

In order to conduct the microstructure analysis of musical behaviour for the three case studies, the SYMP template was deleted so that the new data for this study from each lesson per case study could be inserted. Six independent SYMP projects, which corresponded to the total number of piano lessons, were created. Only four of the six intercommunicating spread-sheet pages of the original SYMP software tool were used in the current study: music information, practice sessions, cues, and practice graph (Demos & Chaffin, 2009) as shown in Appendix 11. Customization of the SYMP software tool was achieved by adding an extra column in order to identify the player, for instance the teacher, student, or both, and to determine the origin of the musical excerpt, whether it was derived from performance or from listening back to the recorded data. Video QDA of auditory feedback in piano lessons through microstructure analyses of musical behaviour are discussed in detail in Chapter 8.

5.8.7 MIDI QDA: additional visual feedback across case studies

The fourth type of data analysis undertaken in this current study was MIDI QDA. This type of analysis was feasible as the MIDI data were generated from the technology used in the piano lessons when recording and saving data in the DAW software. Through MIDI QDA, additional visual feedback enabled examination of the relationship between MIDI parameters, such as MIDI notes colours, sizes, asynchrony, key velocity numbers, and pedalling use activity, and agreed musical performance parameters in terms of observed learning priorities and performance goals. The forms of additional visual feedback which were available to the teacher and student pair when technology was applied in the piano lessons were either in real-time or post-hoc, and were accompanied, or not, by auditory feedback. MIDI QDA for additional visual feedback available in piano lessons is discussed in detail in Chapter 9.

5.8.8 Interview QDA: participant perspectives across case studies

The final data analysis approach included interview QDA. Two interview recordings from each of the six participants were collected after each piano lesson, totalling twelve interviews. The interviews were transcribed by a professional team, as were the verbalizations on the videoed lessons, and checked by myself for accuracy of transcription. Once the transcripts were deemed accurate, Word documents of interviews were imported to CAQDA software.

Although the interview QDA was not conducted in such depth as the video QDA, it gives insights into the current study. Selections from the interview data were chosen to illustrate the perspectives of the teachers and students after each of the two piano lessons with applied technology. As the main data source was the video data, the interviews were conducted to seek potential similarities, differences, supporting and complementary information about the findings which were observed through the video QDA. In addition, further data were collected in follow up email correspondence with the teachers. The Interview QDA is discussed in detail in Chapter 10.

5.9 Trustworthiness in this study

This qualitative research study is based on the term 'trustworthiness' (Guba, 1981; Shenton, 2004). Guba (1981) proposed four criteria to ensure trustworthiness in qualitative research: credibility, transferability, dependability, and confirmability, in replacement of the four criteria commonly adopted in quantitative reach: internal validity, external validity/generalizability, reliability, and objectivity, respectively (Denzin & Lincoln, 2000; Shenton, 2004). The four aspects of trustworthiness in an inquiry are: 'truth value, applicability, consistency, and neutrality' (Guba, 1981, p.80), which can be affected by 'masking or competing factors, situational variations, instrumental drift or decay, and investigator predilections' (Guba, 1981, p.81).

The trustworthiness in qualitative research conducted in a specific context with purposeful participants is supported by the four quality criteria proposed by Guba (1981, pp. 79-80): credibility, transferability, dependability and confirmability. Credibility addresses the 'confidence in the "truth" of the findings', while transferability allows findings to be applicable in similar contexts and participants (Guba, 1981, p.79). Dependability needs findings to be 'consistently repeated' if the study is replicated, for example by another researcher, in the same context and participants (Guba, 1981, p.80). Finally, confirmability relates to findings which emerge solely from the data as ‘a function solely of [participants]’ and are not influenced by ‘motivations, interests, perspectives, and so on of the inquirer’ (Guba, 1981, p.80).

In order to achieve trustworthiness in this study, I have aimed to apply the four quality criteria suggested by Guba (1981). I have attempted to achieve credibility by demonstrating and presenting ‘a true picture of the phenomenon under scrutiny’ (Shenton, 2004, p. 63). Credibility is achieved by adopting two of the six treatments suggested by Guba (1981, p. 83): to ‘use persistent observation [and] do triangulation’. Triangulation occurs when ‘researchers take different perspectives on an issue under study […] in answering research questions’ (Flick, 2009, p. 445). Therefore, an effort to increase transferability and confirmability in this study was made by triangulating different data sources and methods. Transferability is allowed in this study when ‘sufficient detail of the context of the fieldwork’ has been provided ‘and whether the findings can justifiably be applied to [a similar] setting’ (Shenton, 2004, p. 63). Transferability was achieved by following the suggestions by Guba (1981, p. 83): to ‘collect thick descriptive data, and do theoretical/purpose sampling’.

Dependability—or reliability—was achieved through the consistency of the methodological tools, such as data collection and analysis, which I used in this study in order ‘to enable a future investigator to repeat the study’ (Shenton, 2004, p. 63). Yin (2014, p. 84) suggested adopting a systematic protocol for data collection in case study approaches. In order to increase dependability in this study, a systematic protocol was adopted when carrying out the data collection for observations and interviews (see Appendices 2 and 3 for videoed lessons and interview protocols) which drew on the case study approach supported by Yin (2014, p. 84). It needs to be emphasised here that while the current study is an action case study, it nonetheless involves aspects of case study approach. Although the study was not repeated by another researcher in the same context and participants, dependability was assured by using ‘overlap methods’, for example through method triangulation, as suggested by Guba (1981, p.

83). In order to ensure confirmability, I have demonstrated that findings emerged ‘from the data and not [my] own predispositions’ (Shenton, 2004, p. 63) and it was achieved by doing triangulation.

Triangulation was central to achieve trustworthiness in this exploratory action-case study approach. Denzin (cited in Flick, 2009, p. 444) proposed ‘four types of triangulation’ approaches to endure validation, or transferability, in qualitative research: using multiple, varied or different data sources, investigators, theories, and method. Two of the four forms of triangulation strategies suggested by Denzin were applied in this study: triangulation of data, and method.

Triangulation of data encompassed three data sources: videoed lessons, technology-generated MIDI data, and also audio-recorded interviews. MIDI data is a new type of data ‘opening up further possibilities of triangulation with traditional types of data’ (Flick et al., 2004, p. 179). Triangulation of method was applied in this study which used thematic analysis for video observations and interviews, microstructure analysis of musical behaviour within observations, and MIDI QDA within observations which allows capturing ‘different aspects of the research issue’ (Flick et al., 2004, p. 180).

Triangulation of the cases allowed a ‘case-related analysis of both types of data and also makes it possible to compare and interrelate, in the context of a single-case, the different perspectives opened up by the methodological approaches’ (Flick et al., 2004, p. 181). For example, in this study, participants who were observed in the videoed lessons were also those who were interviewed, and their MIDI data were generated within their videoed lessons. Thus, I have attempted to guarantee trustworthiness and quality criteria in this study through triangulation of data, methods and case as proposed by Guba (1981) and Flick (2004).

5.10 Summary

Chapter 5 reported on the methodology of this study. This chapter described the research journey and discussed the decisions which were made and which led to the methodology adopted. The definitive research design for the main study was clarified after successive pilot case studies in the UK. The most appropriate research design was found to be an exploratory action-case study approach. The research cohered around the investigation of one-to-one HE level piano lessons in which the teacher and student worked on a chosen memorized piece where the application of technology was mediated by myself in the role of facilitator. Three case studies at HE level in Brazil were selected from a pool of participants for this study. Data collection involved the video observation of piano lessons with the application of technology-mediated feedback, MIDI data which was generated in the DAW software used to record and save performance-related data, and semi-structured interviews held with the participants separately after the piano lessons.

Video data were the main sources for QDA alongside technology-generated MIDI data while interview data were complementary and used to support or contradict observations. The triangulation of data, method and case allowed trustworthiness and quality criteria in this study. The interconnection between the various data analysis approaches undertaken in this study assisted understandings of the application of technology-mediated feedback in the HE level piano studio.

Multi-method data analysis approach was used in this study. Data analysis involved five perspectives. The first perspective drew on the video QDA to focus on verbal and non-verbal feedback on musical performance parameters. The second perspective focused on the video QDA to identify the pedagogical uses of technology-mediated feedback over time. The third perspective focused on the video QDA to identify additional auditory feedback use in piano lessons through microstructure analysis of musical behaviour. The fourth perspective drew on MIDI QDA to identify additional visual feedback use in piano lessons. Finally, interview QDA was conducted in order to complement and support the findings of the multi-method approach to the video QDA and MIDI QDA.

In summary, through the research design adopted in this current study, there was an attempt to address the following three research questions.

1. What is the nature of feedback in higher education piano learning and teaching when technology-mediated feedback is applied?

The first question was addressed by adopting a multi-method approach to qualitative data collection and analysis with a quantitative component (see Chapter 6). This stage of the research design included mainly video-based observation of two piano lessons with the use of technology-mediated feedback per each of the three case studies. This study focused on three meta-categories reported in the synthesis of feedback literature (see Table 4.1 in Chapter 4). A cross-tabulation between verbal or non-verbal behaviours and the musical performance parameters related to them, suggested the types of verbal and non-verbal feedback which were available within each case study, and across case studies. Additional auditory and visual feedback which was generated by the applied technology was also examined through a microstructure analysis of musical behaviour, specifically musical practice (playing) and listening back (see Chapter 8), and MIDI QDA, respectively (see Chapter 9).

2. How is technology-mediated feedback applied in higher education piano learning and teaching?

The second question was also addressed by adopting a multi-method approach towards qualitative data collection and analysis. This stage of the research draws mainly on the video QDA for the use of technology-mediated feedback in order to investigate how technology is applied in each case study (see Chapter 7). Video QDA in relation to the microstructure analysis of musical behaviour and MIDI QDA are also examined in order to evaluate the application of technology in the three case studies in HE level piano learning, through either additional auditory or visual feedback (see Chapters 8 and 9, respectively).

3. Does the application of technology-mediated feedback enhance higher education piano learning and teaching, and improve student performance in piano lessons?

The third question was also addressed by adopting a multi-methods approach, including qualitative data collection and analysis. My perspectives as the researcher are shown in the video and MIDI QDA (Chapters 6 to 9), and teacher and student participant perspectives are shown in the interviews (Chapter 10). These perspectives are compared in order to see whether findings from the interviews can complement findings from the observations and MIDI-generated data. Comparisons are drawn between my views as the researcher and the views of the participants regarding the effect of the application of the technology-mediated feedback on student learning and performance in an HE piano studio.

The interrelationships between the different approaches toward data collection and analysis thus allow for a greater understanding of whether the application of technology-mediated feedback enhances student piano learning and performance in an HE piano studio (see Chapter 11). Contributions of this study are revealed on the nature of feedback, pedagogical use of technology, and musical performance parameters which are more likely to be enhanced in HE piano learning and performance in HE (see Chapter 12).

6 Video QDA: verbal and non-verbal feedback across three case studies

6.1 Introduction

In this chapter, findings from video qualitative data analyses (video QDA) are reported for types of verbal and non-verbal feedback related to the musical performance parameters within each of the three case studies and across these studies. Patterns of verbal and non-verbal behaviours—including feedback—were investigated using CAQDA software (QSR International NVivo10). Thematic analyses were initially used to investigate systematically teacher and student verbal and non-verbal behaviours (see Appendices 7 and 8 for the full lists of sub-categories). Three categories of musical performance parameters (see Appendix 9 for the full list of sub-categories), namely, music, performance, and technology, which were worked on in piano lessons, were also investigated in the thematic analysis. Types of verbal and non-verbal feedback were generated. All investigations were carried out in accordance with the synthesis of verbal and non-verbal feedback, and musical performance parameters in Chapter 4 and the theoretical framework of this study as described in Chapter 5.

This chapter addresses the context of each case study in turn with regard to talk, playing and feedback in three steps. First, all teacher and student talk, piano playing, and feedback (verbal and non-verbal feedback) were examined. Second, talk, playing and feedback per individual teacher and student were also investigated. The third step involved analysis of types of verbal and non-verbal feedback, which were addressed in relation to musical performance parameters in the three main areas, namely, music, performance and technology. Talk, playing and types of feedback were investigated for duration within and across three case studies. An additional focus on types of feedback for frequency was also examined. Talk encompassed the sum of all sub-categories of verbal behaviours. Playing involved the sub-category, playing, selected from all non-verbal behaviours. Feedback (verbal and non-verbal feedback) encompassed types of feedback generated from the cross-tabulation between behaviours and musical performance parameters. Then, further comment on general feedback is made across the three case studies. The video QDA also focuses on talk, playing and feedback in order to gain a comprehensive view of pedagogical characteristics of the lesson, and the nature of feedback when technology-mediated feedback was applied in each of the three case studies. Note: This chapter reports on teacher and student behaviours rather than my behaviour as the researcher; this will be addressed in Chapter 7 with reference to the use of technology.

6.2 Impressions on each case study

The three regular pairs of teachers and students in Higher Education chose to work on selected movements of Western classical sonatas during both lessons. In case study A, the regular teacher and student pair chose to work on the second movement in G major of the Mozart Piano Sonata No. 16 in C major, K. 545 (see Figure 6.1).

Figure 6.1 Mozart Piano Sonata No. 16 in C major, K. 545, fragment, second movement, bars 1-4 (Leipzig: Peters, 1938)

Source: IMSLP website http://imslp.org/

My first impression of case study A was that teacher A and student A were engaging with and incorporating technology-mediated feedback into their lessons. However, there was apparent anxiety as to how the lesson would be conducted, and what musical parameters the technology could inform. Student A seemed very interested in technology and was already familiar with the DAW software used in the lesson. The prior engagement of this student with DAW software seemed to make the teacher feel more confident about the applied technology in the lessons. In this sense, student A assisted the teacher in establishing the relationship between what was being shown on the computer screen and the musical notation on the score. This might also have helped teacher A to be less anxious about the application of technology in the lessons. Both teacher and student in case study A not only incorporated the technology in lessons, but were willing to explore its application in a piano studio. They also found their own ways of applying the technology and supporting the learning and teaching of selected musical performance parameters in order to improve student performance of specific excerpts of the chosen piano piece.

In case study B, the teacher and student had chosen to work on the first movement of the Beethoven Piano Sonata No. 9 in E major, Op. 14 No.1 (see Figure 6.2).

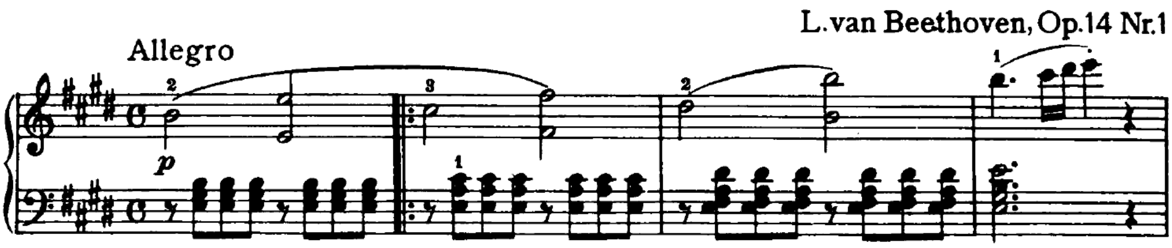


Figure 6.2 Beethoven Piano Sonata No. 9 in E major, Op. 14 No. 1, fragment, first movement, bars 1-4 (Leipzig: Peters, 1920)

Source: IMSLP website http://imslp.org/

My first impression of case study B is that both teacher and student seemed to be open to the research project. However, the teacher wanted to ensure full understanding of the possibilities of using the technology beforehand in order to plan the lesson. After my brief explanation of the project, some suggestions were made by the teacher on how the technology could be used in the lesson. As with the student in case study A, the student in case study B had previous experience with the DAW software, but for purposes other than piano practice. Off-task verbal behaviours observed at the beginning of the lesson revealed the reciprocal support between student B and teacher B, which operated throughout the lesson.

In case study C, the teacher and student had chosen to work on the first movement of the Mozart Piano Sonata No. 2 in F major, K. 280 (see Figure 6.3).

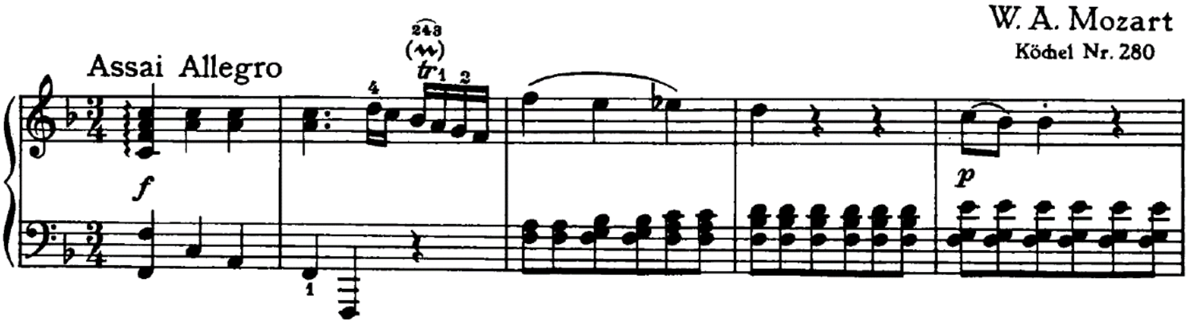


Figure 6.3 Mozart Piano Sonata No. 2 in F major, K. 280, fragment, first movement, bars 1-5 (Leipzig: Peters, 1938)

Source: IMSLP website http://imslp.org/

My first impression of case study C is that the teacher was somewhat disassociated in conducting a piano lesson with student C by applying technology in the piano lesson. From the beginning, it was unclear whether there was an engagement between the participants and the application of technology-mediated feedback, and also with myself as a researcher. Teacher C showed reluctance towards incorporating the technology in the piano lesson and appeared to have little idea as to how to conduct the piano lesson with the available technology-mediated feedback. For a moment, as a researcher, I felt that either I might not have explained the research project adequately or that the teacher might not have understood the research project, even though the teacher had asked clarifying questions on how to plan the piano lesson with technology. At first it seemed that the teacher would give the piano lesson as usual, without considering the application of technology.

6.3 Talk, playing and feedback across case studies

The first step in the focus on technology-mediated feedback involved looking at the overall trends of talk, playing and feedback within and across the three case studies in order to illustrate their respective characteristics, differences and similarities. In the video QDA, talk encompassed the sum of verbal behaviours between teacher and student in each lesson (see Appendix 7 for verbal behaviour raw data). Playing encompassed only one sub-category, namely playing, of all non-verbal behaviours by either the student or teacher (see Appendix 8 for non-verbal behaviours raw data). Feedback was based on the fifteen most observed verbal and non-verbal types of feedback, generated by the cross-tabulation of themes, which were communicated by either teacher or student on aspects of the music, performance and technology in their piano lessons (see Appendix 10 for the raw data in respect of cross-tabulation and prospective types of verbal and non-verbal feedback on musical performance parameters). The descriptive statistics plotted in Table 6.1 show time spent on the sum of teacher and student behaviours for talk, playing and feedback and mean values over lessons per case study and across the six lessons.

Table 6.1 Talk, playing and feedback time (%) in lessons 1 and 2, and mean values, per case study

Case study		Time (%)		
		Talk	Playing	Feedback (V + NV)
		SUM	SUM	SUM
A	Lesson 1	52	16	36
	Lesson 2	50	25	40
	Mean	51	20	38
B	Lesson 1	49	47	38
	Lesson 2	51	40	33
	Mean	50	43	35
C	Lesson 1	54	42	38
	Lesson 2	50	51	36
	Mean	52	46	37
Mean over six lessons		51	37	37

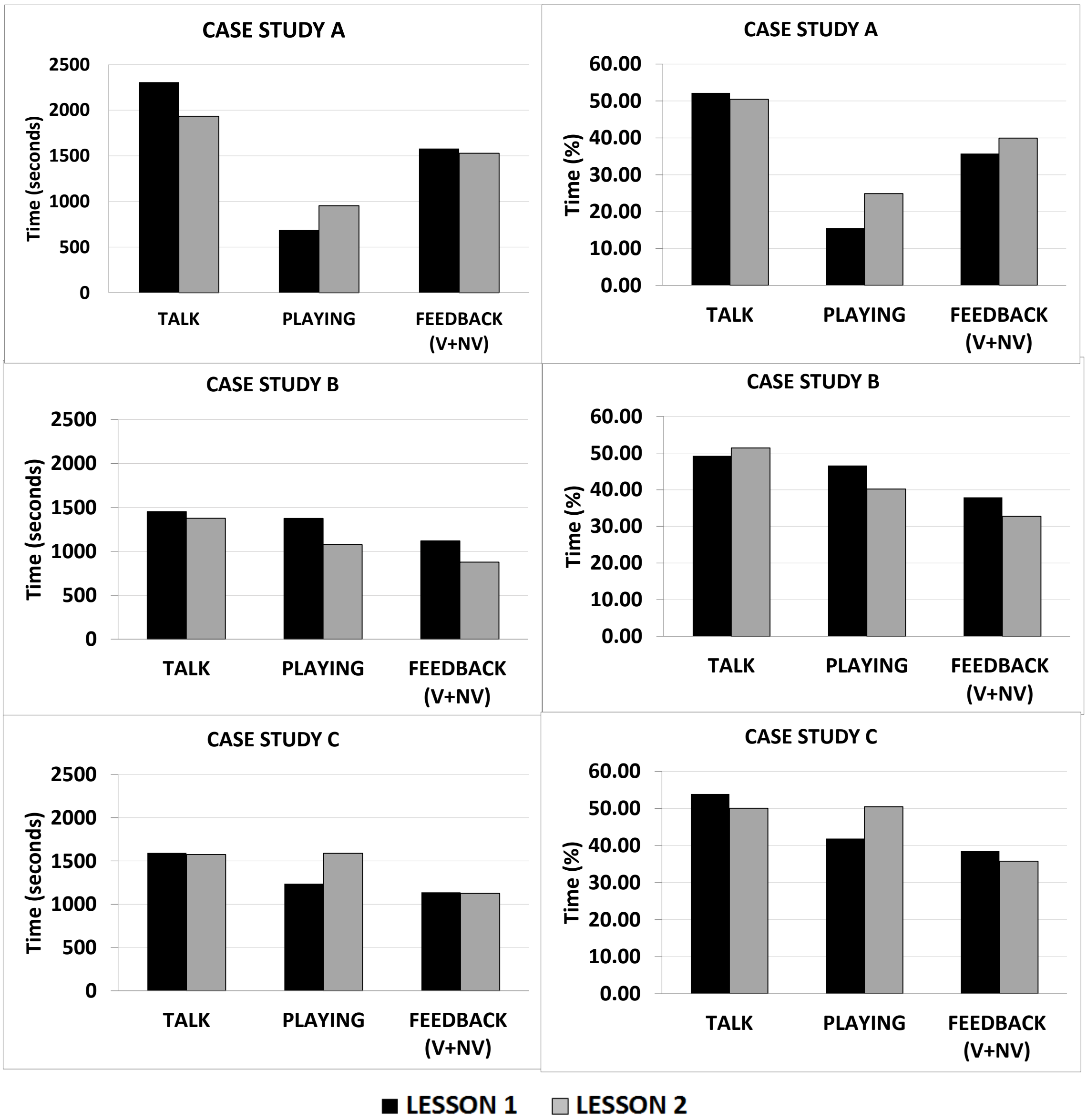


Figure 6.4 Time spent (seconds and %) on talk, playing and feedback per case study and lesson

Key: V stands for verbal feedback and NV stands for non-verbal feedback.

Figure 6.4 illustrates the length of time spent on the three main observed behaviours, talk, playing and feedback, per case study for two lessons in two different time unit scales. In the first set of bar charts for each case study, the lesson one and two bars show the comparative time spent on talk, playing and feedback in seconds. The second set of bar charts for each case study indicates the time spent per behaviour as a percentage of the total lesson. The need to look at time in seconds and percentages was due to the differing total lesson time per case study (see Table 6.2). For example, of the six observed lessons, lesson 1 in case study A had a non-typical lesson time in that it was much longer than the other five lessons. Since verbal and non-verbal feedback were generated by cross-tabulation of behaviours and musical performance parameters, the recordings showed that talk, playing and verbal and non-feedback were not always separate or sequential activities, but simultaneous at some moments. Percentages of talk, playing and feedback added up to more than 100%, because behaviours often overlapped. In addition, talk not only incorporated the sum of verbal behaviours but also verbal feedback.

Table 6.2 Total lesson time per case study

Case study	Total lesson time (seconds)	
	Lesson 1	Lesson 2
A	4420	3831
B	2951	2677
C	2957	3145

Across the three case studies, a lot of time was spent on talking. Time devoted to talking in lessons 1 and 2 combined, ranged from 49% to 54% of lesson time across all six lessons (*M* = 51%). The main difference between case studies was in terms of the length of time spent playing (*M* = 37%). Average playing time was observed less in case study A than in the other case studies. Time devoted to playing in case study A ranged from 15% to 25% in lessons 1 and 2, respectively (*M* = 20%). Time devoted to playing in case studies B and C were similar, ranging from 40% to 47% (*M* = 43%) in case study B, and from 42% to 50% (*M* = 46%) in case study C. Feedback, both verbal and non-verbal, represented a relatively high length of time across case studies, averaging 37% of all six lessons with a range of between 33% and 40%.

Video QDA within each of the three case studies is discussed here. In case study A, average talk and feedback time were both high and evenly distributed throughout with 51% and 38% over lessons, respectively. Although playing was observed less, it increased between lesson 1 and lesson 2, from 15% to 25% respectively. In case study B, average talk and playing time were high with approximately 50% and 43% over lessons 1 and 2, respectively. Playing also decreased from 47% to 40% while talk increased from 49% to 51%. Feedback was observed less decreasing from 38% of the time in lesson 1 to 33% in lesson 2. In case study C, average talk and playing time were high with approximately 52% and 46% respectively in comparison with an average feedback time of 37% across lessons. Talk decreased from 54% to 50%, while playing increased from 42% to 50% between lesson 1 and lesson 2. In general, less talk in the second lesson led to an increased length of time spent playing.

6.4 Talk, playing and feedback by teachers and by students

The second step in the focus on technology-mediated feedback involved examining specific details of talk, playing and feedback by teachers and students within and across case studies. The aim was to illustrate the characteristics of each case study and their respective differences and similarities. Table 6.3 shows time spent for individual teacher and student behaviours for talk, playing and feedback and mean values over lessons per case study and across the six lessons.

Table 6.3 Talk, playing and feedback time (%) in lessons 1 and 2, and mean values, per participant per case study

Case study		Time (%)					
		Talk		Playing		Feedback (V + NV)	
		T	S	T	S	T	S
A	Lesson 1	38	14	1	15	28	8
	Lesson 2	37	13	2	23	33	6
	Mean	38	14	1	19	31	7
B	Lesson 1	42	7	1	45	38	0
	Lesson 2	41	10	1	40	31	1
	Mean	42	9	1	42	34	1
C	Lesson 1	46	8	16	26	35	4
	Lesson 2	45	5	21	30	33	2
	Mean	45	7	18	28	34	3
Mean over six lessons		42	10	7	30	33	4

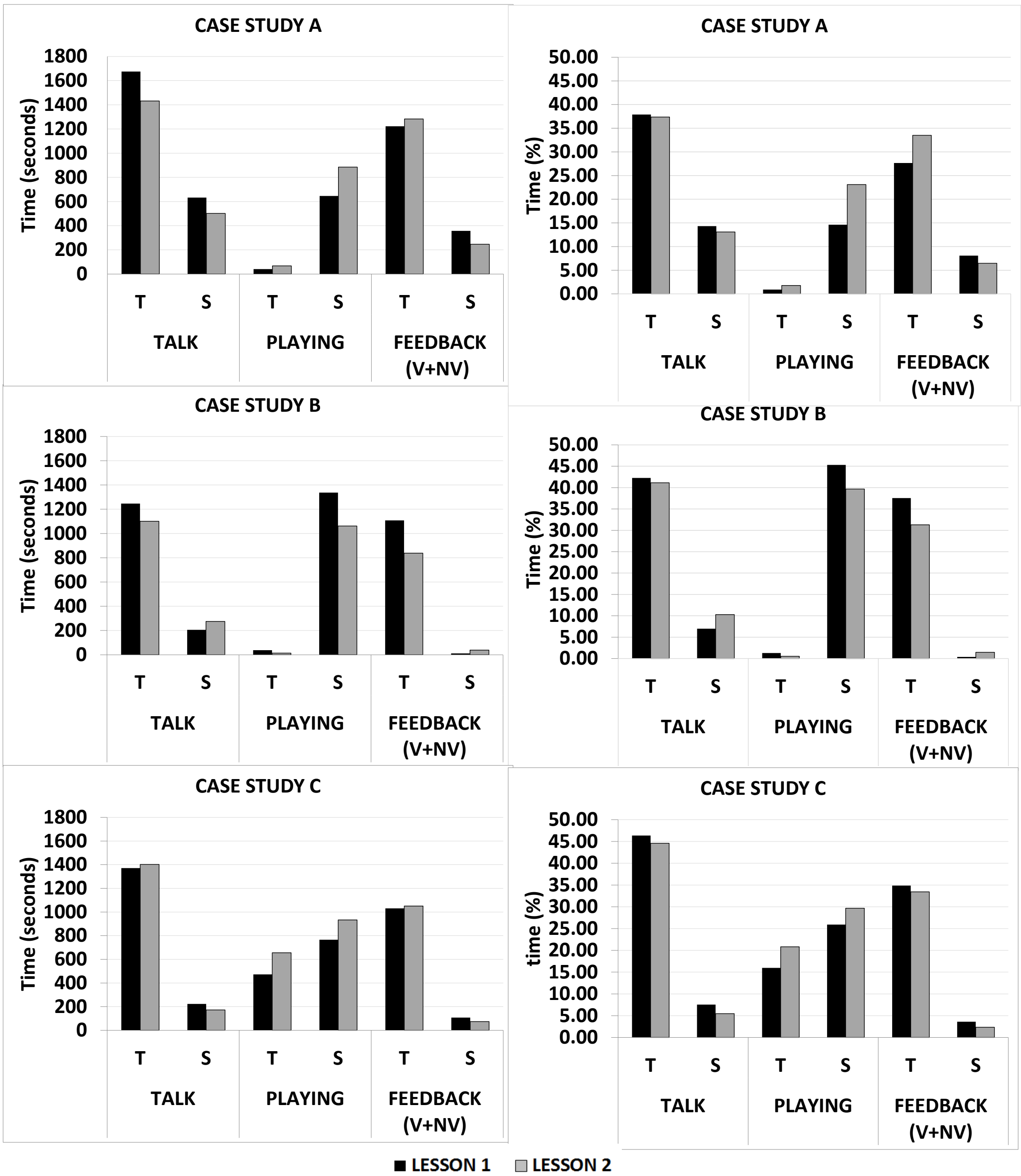


Figure 6.5 Time spent (seconds and %) on talk, playing and feedback per participant per case study

Key: T represents teacher and S represents student.

Figure 6.5 shows the distribution of time spent on talk, playing and feedback for each student and teacher. Descriptive statistics are given per case study in two time unit scales, seconds and percentages. As mentioned earlier, video QDA addresses findings in percentages rather than in seconds since the length of all six lessons were different across case studies.

In ranking order, most of the lesson time across case studies was devoted to teacher talk, student playing, and teacher feedback. Average teacher talk time accounted for 42% of total lesson time across all six lessons, with slight differences between case studies. Average playing time was mostly accounted for by students, with 30% of total lesson time across all six lessons. However, average student playing time differed across case studies, with 19%, 42%, and 28% of total lesson time being taken up by playing in case studies A, B and C respectively. Observed differences on student playing time suggest each case study demonstrates a particular teaching pedagogical style. Feedback, both verbal and non-verbal, was predominantly delivered by the teacher, accounting for 34% of total lesson time across all six lessons with slight differences between case studies.

In contrast, minimal time was spent on student talk, teacher playing, and student feedback across the three case studies. Average student talk time accounted for 10% of total lesson time across all six lessons. Average student talk time in case study A accounted for 14% over lessons, suggesting that this particular student was making more comments in lessons than the students in the other two case studies. Average teacher playing time was also minimal, accounting for 1% in case studies A and B. However, teacher playing time was substantially higher in case study C where it accounted for 18% of the total lesson time. This evidence suggests that this particular teacher was modelling the desired musical behaviour as well as talking, corroborating the existence of different teaching styles commented on earlier. Average student feedback time was minimal across the case studies, accounting for 4% of total lesson time across all six lessons. Student feedback time in case study A accounted for approximately 7% across lessons, suggesting that this particular student was self-evaluating their performance within lessons.

In case study A, despite the predominance of teacher talk and feedback in lessons, a greater length of time was given to student talk and feedback than in other case studies, accounting for approximately 14% and 7% of total lesson time respectively. This evidence suggests that student A was given or created greater opportunity to make comments on their performance within lessons. In addition, between lessons 1 and 2 student playing increased, from 15% to 23%, and teacher feedback, from 28% to 33%. This evidence would indicate that teacher feedback and student playing are closely related. In the context of a lesson, student playing occurs in response to teacher feedback which implies a circular or dependent relation between teacher and student. A slight decrease in student feedback, from 8% to 6% of total lesson time, was also observed between lessons 1 and 2. This evidence might imply that student A had an active role in their learning process by making comments during these lessons.

In case study B, average teacher talk time was consistent at 42% of the total time over lessons. Average student playing time also accounted for 42% of the total time over lessons. There was a slight decrease in time spent on both student playing and teacher feedback which decreased from 45% to 40% and from 37% to 31% respectively. This parallel decrease reflects the fact that the less the student played, the fewer the comments made by the teacher. This evidence implies that there is a dependent relationship between teacher feedback and student playing as also observed in case study A.

In case study C, average teacher talk accounted for 45% of total lesson time with a slight decrease of 1% between lessons 1 and 2. Student C played for 28% of the time, while teacher C played for 18% of the total lesson time across lessons. This was significantly longer than the teachers in other case studies who only played for 1%. This difference might be related to the particular teaching style of teacher C who used modelling in both lessons. There was a minor increase in the time spent, both on teacher playing, from 16% to 21%, and on student playing, from 26% to 30% between lessons 1 and 2. Average teacher feedback time accounted for 34% with a slight decrease of 1% between lessons 1 and 2. Teacher feedback and student playing did not present a parallel pattern in case study C as was found in the other case studies. However, if teacher playing is seen as another form of non-verbal feedback, the data from case study C suggest that at least half of the available time in each lesson was spent on feedback.

6.5 Verbal and non-verbal feedback across case studies

Finally, the third step of the focus on technology-mediated feedback involved an examination of the types of verbal and non-verbal feedback given by the teacher and student. These were linked to the following three areas: *music*, for example musical notation and musical structure of the piece; *performance*, especially dynamics, tempo, and articulation; and *technology*, namely MIDI parameters. This was done in order to illustrate in more detail the differences or similarities within and across case studies.

Table 6.4 shows time spent for individual teacher and student verbal and non-verbal feedback, and mean values over lessons per case study and across the six lessons. Figure 6.6 is solely feedback focused. It shows specific information relating to each teacher and student in regard to the length of time spent on verbal and non-verbal feedback on the three focus aspects of musical performance. Descriptive statistics on verbal and non-verbal participant feedback per case study are plotted in seconds and as a percentage of the total lesson length. The charts provide an overview of how much time was spent on verbal and non-verbal feedback in the following three sub-categories: music, performance, and technology.

Table 6.4 Verbal and non-verbal feedback time (%) in lessons 1 and 2, and mean values, per participant per case study for the three foci (music, performance, technology)

Case study		Time (%)													
		Verbal						Non-verbal					
		Music		Performance		Technology		Music		Performance		Technology	
		T	S	T	S	T	S	T	S	T	S	T	S
A	Lesson 1	8	2	9	0	6	3	0	1	4	2	1	1
	Lesson 2	4	0	7	0	6	2	3	3	12	1	2	0
	Mean	6	1	8	0	6	2	1	2	8	1	1	1
B	Lesson 1	6	0	8	0	7	0	2	0	15	0	0	0
	Lesson 2	5	0	8	0	6	1	1	0	11	0	1	0
	Mean	5	0	8	0	6	1	1	0	13	0	1	0
C	Lesson 1	6	0	16	0	1	0	1	0	11	4	0	0
	Lesson 2	9	0	16	0	2	0	1	0	6	2	0	0
	Mean	7	0	16	0	2	0	1	0	8	3	0	0
Mean over six lessons		6	0	11	0	5	1	1	1	10	1	1	0

Key: T represents teacher and S represents students.

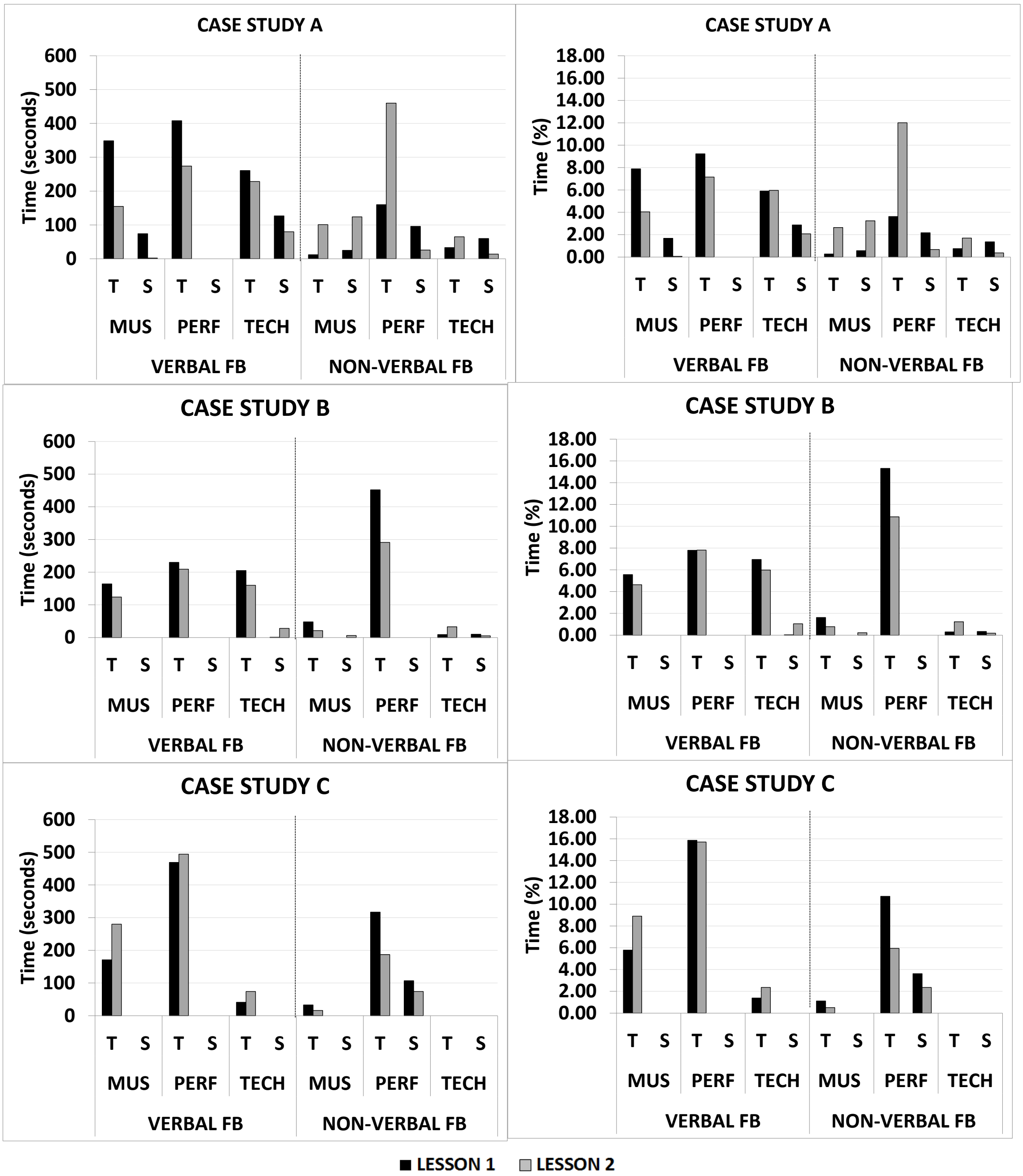


Figure 6.6 Time spent (seconds and %) on feedback (verbal and non-verbal feedback) per participant per case study for the three foci (music, performance, technology)

Key: T represents teacher and S represents students. Mus stands for music, Perf for performance, and Tech for technology. FB describes feedback.

Verbal feedback included verbal behaviours such as providing information, giving directions and asking questions. Non-verbal feedback was linked to behaviours such as head movements and other physical gesturing with the body, hand, or foot, pointing to the music score or computer screen, as well as playing the piano and singing. Each of these categories could be linked to one of the three analytical sub-categories. First, the sub-category of music measured the length of time devoted to aspects of music score such as music structure, harmony and tonality of the chosen piece. Second, the length of time spent on aspects of student performance measured dynamics, articulation, rhythmic and melodic accuracy, and phrasing. Third, the sub-category of technology measured the time spent on MIDI parameters, such as MIDI note sizes, colours, asynchrony, key velocity number, MIDI recording version use, and digital piano use.

Overall, the three case studies demonstrated different patterns of verbal and non-verbal feedback, although there were some similarities. Verbal feedback tended to be relatively evenly distributed across the three categories of music, performance, and technology in case studies A and B, but biased towards performance in case study C. In this case study, teacher C spent much less time focused on technology (M = 2%) compared to teachers A (M = 7%) and B (M = 7%). Teacher C devoted approximately double the length of time to performance aspects (M = 16%) when compared to teachers A (M = 8%) and B (M = 8%). There was a significant difference for student verbal feedback on technology across case studies. Students A and B devoted 2% and 1% of the lesson time on technology, respectively, while student C did not contribute to it at all. With regard to non-verbal feedback, the behaviour of each teacher was biased towards performance. Teachers A and C spent 8% of lesson time across lessons in delivering non-verbal feedback on performance while teacher B devoted 13% across lessons. The following paragraphs report on the nature of feedback within each of the three case studies with regards to time.

In case study A, with regard to individual teaching styles, teacher A involved much more non-verbal feedback in the second lesson (M = 17%) than in the first lesson (M = 5%). Average teacher verbal and non-verbal feedback on performance was predominant throughout lessons accounting for 16% of the total lesson time, with both verbal and non-verbal feedback accounting for 8% each. Average teacher verbal feedback emphasized performance, then music, accounting for 8% and 6% of total lesson time, respectively. Teacher verbal feedback on technology was consistent, accounting for 6% of total lesson time throughout lessons. Student verbal and non-verbal feedback occurred for all types of feedback, apart from verbal feedback on performance. Average student feedback on technology stood at 3% of total lesson time. The total student feedback time accounted for 7%. This indicates that student A is likely to be having an input in the learning process. This evidence indicates that the student was supporting the teacher by providing comments on technology in lesson 1 (see Table 6.6 for an example of student verbal feedback on technology). Teacher A adopts a more collaborative teaching style which arguably facilitates a more dynamic learning process. In case study A there are more opportunities for the student to engage in verbal and non-verbal behaviours, and thus to develop a more independent and autonomous learning style.

In case study B, although the teacher used more verbal than non-verbal feedback, 15% of the total lesson time was spent on non-verbal feedback. Teacher B verbal feedback was relatively evenly distributed throughout the lessons, emphasizing performance, technology and music, accounting for 8%, 6% and 5% of total lesson time, respectively. Similar to teacher A, teacher B involved non-verbal feedback on performance accounting for 13%. However, teacher B spent little time delivering non-verbal feedback on music (M = 1%) and on technology (M = 1%). There was an almost total absence of student feedback in case study B. Student verbal feedback on technology stood for 1% of total lesson time over lessons. Student B spent no time on the observed forms of non-verbal feedback. This evidence suggests a strong master-apprentice model of teaching, with teacher verbal behaviour dominant.

In case study C, the teacher also emphasised verbal feedback on performance which stood at 16% in each lesson. However, teacher C spent less time delivering verbal feedback on music and technology, accounting for 7% and 2%, respectively. In contrast, student C spent no time on the observed forms of verbal feedback. Similar to teachers A and B, teacher C involved non-verbal feedback on performance, accounting for approximately 8%. The student only contributed 3% of average non-verbal feedback on performance. While teacher A adopts a more collaborative teaching style, both teachers B and C demonstrate the master-apprenticeship model of piano learning and teaching. Teacher B dominates verbally whilst teacher C spends more time actually playing, and students B and C contribute to the lessons by playing.

In this video QDA, the types of verbal and non-verbal feedback in each lesson per case study were quantified in relation to two perspectives: their duration in the total lesson time, and their frequency referenced. The video QDA of the number of references of types of feedback complements the video QDA of the time spent on the same type of feedback. It appears that observed types of feedback were high in terms of frequency and short in terms of duration.

Table 6.5 shows the frequency for individual teacher and student verbal and non-verbal feedback, and mean values over lessons per case study and across the six lessons. In Figure 6.7, complementary data are provided about the frequency of verbal and non-verbal feedback on music, performance and technology per participant and per case study. The charts provide an overview of how often teacher and student verbal and non-verbal feedback occurred in the three aspects of musical performance parameters.

Table 6.5 Verbal and non-verbal feedback frequency (%) in lessons 1 and 2, and mean values, per participant per case study for the three foci (music, performance, technology)

Case study		Frequency (%)											
		Verbal						Non-verbal					
		Music		Performance		Technology		Music		Performance		Technology	
		T	S	T	S	T	S	T	S	T	S	T	S
A	Lesson 1	31	7	23	0	24	14	6	0	22	26	18	28
	Lesson 2	28	1	13	0	33	15	21	1	54	7	14	4
	Mean	30	4	18	0	28	15	14	0	38	16	16	16
B	Lesson 1	24	0	39	0	37	0	13	0	80	0	4	3
	Lesson 2	21	0	40	0	31	8	9	3	71	0	14	3
	Mean	23	0	40	0	34	4	11	1	75	0	9	3
C	Lesson 1	28	0	65	0	8	0	30	0	58	12	0	0
	Lesson 2	34	0	55	0	11	0	27	0	52	21	0	0
	Mean	31	0	60	0	9	0	29	0	55	17	0	0
Mean over six lessons		28	1	39	0	24	6	18	1	56	11	8	6

Key: T represents teacher and S represents students.

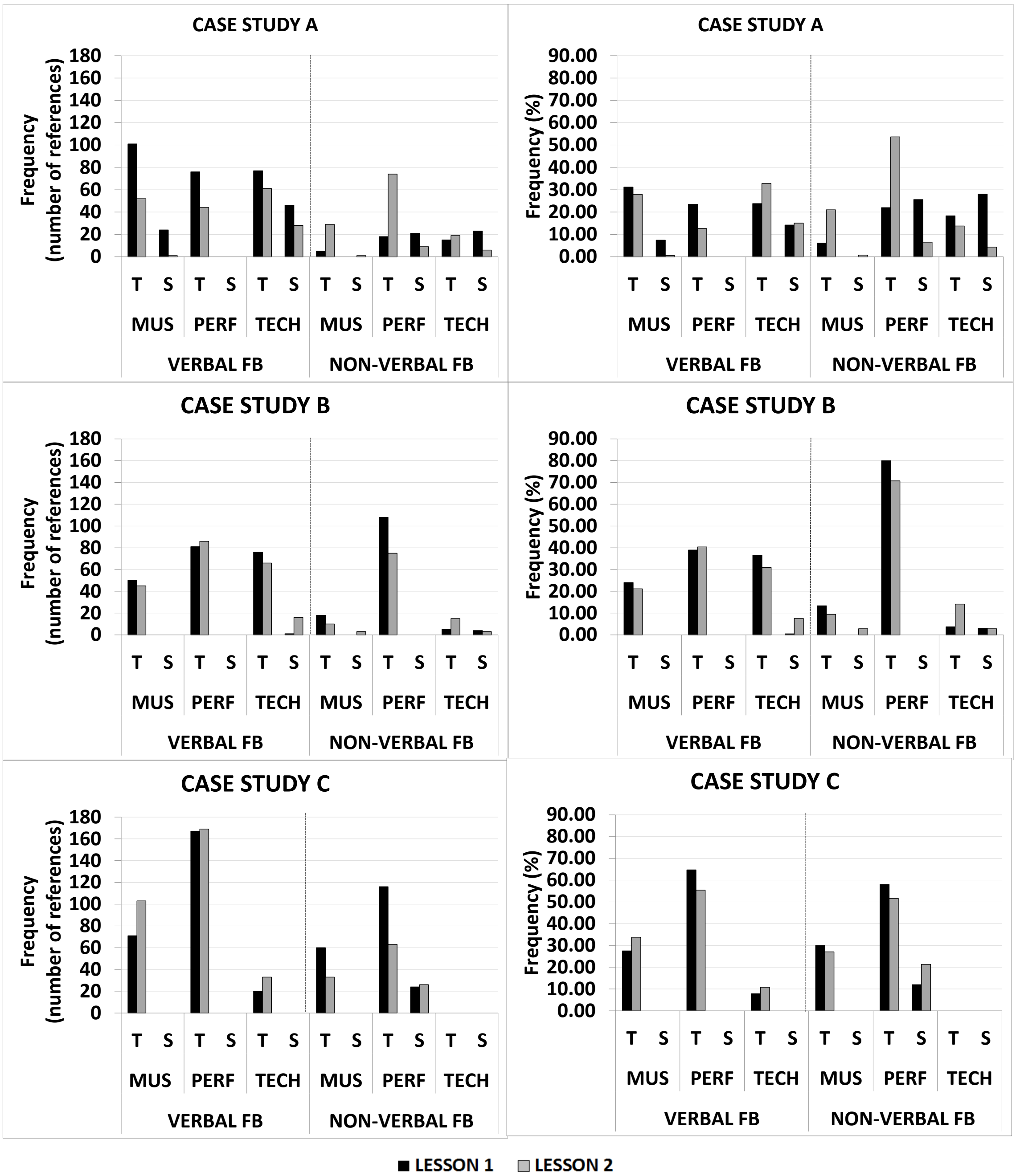


Figure 6.7 Frequency (number of references and %) of verbal and non-verbal feedback per participant per case study for the three foci (music, performance, technology)

Key: T represents teacher and S represents students. Mus stands for music, Perf for performance, and Tech for technology. FB describes feedback.

Overall, instances of verbal and non-verbal feedback tend to be more frequent, based on the number of references coded, and shorter in duration, when comparing the respective percentages given on the observed activities. For example, in case study A teacher non-verbal feedback on performance varied from 4% to 12% of the total lesson time, while the number of references varied from 22% to 54%. In contrast, in case study B, teacher non-verbal feedback on performance varied from 15% to 11% of the total lesson time, whilst the frequency ranged from 80% to 71%. Finally, in case study C the length of time spent on teacher non-verbal feedback on performance varied from 11% to 6% while the frequency of references remained similar, only ranging between 58% and 52%.

Types of verbal feedback were mostly in the form of providing information and giving directions across the three case studies. In addition, asking questions was observed as a form of verbal feedback only in case studies A and B. Verbal feedback was delivered by teachers or students for music, performance and technology. Verbal feedback was related to music when there was a verbal comment on either the music structure or harmony and tonality of the chosen piece. Verbal feedback was linked to performance when there were verbalizations on performance parameters such as dynamics, tempo, articulation, rhythmic accuracy, phrasing, pedalling, technique, motor control issues, and fingering. Verbal feedback was related to technology when comments were made on MIDI parameters such as MIDI notes sizes, colours, asynchrony, key velocity numbers, MIDI recording version use, or digital piano use. Examples of verbal feedback types by teachers and students on music, performance and technology and available per case study lesson are shown in Table 6.6.

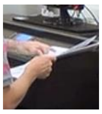
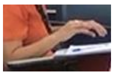
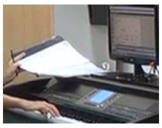
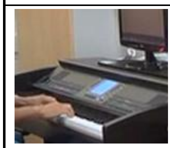
Similarly, types of non-verbal feedback were delivered by teachers and students across the three case studies. Types of non-verbal feedback were self-explanatory; they were related to music, performance, and technology. They were mainly in the form of body and head movements for tempo, such as bouncing the head or body alongside student playing, pointing to the score for musical structure, playing to demonstrate harmony and tonality, and gesturing for tempo. Differences on the types of non-verbal feedback were observed across case studies. For example, playing examples for articulation, and physical touching for motor control issues were noticed in case studies A and C. Similarly, pointing to the computer screen for MIDI parameters, and gesturing for technique and for motor control issues were observed in case studies A and B. Other non-verbal feedback forms were observed in specific case studies, such as playing for technique and tempo, and singing for rhythmic accuracy in case study C. Gesturing as a type of non-verbal feedback was noticed in case study C when snapping fingers and tapping hands or feet for rhythmic accuracy. Gesturing was also noticed in case study B for phrasing, articulation, and dynamics. Examples showing still images from video shots of non-verbal feedback on music, performance and technology across the case studies are illustrated in Table 6.7. It should be noted that in order to maintain anonymity, the selected images do not show faces of participants.

Table 6.6 Examples of verbal feedback on music, performance, and technology delivered by teacher and student per case study and per lesson

Musical performance parameters	Examples of verbal feedback	Case study and lesson
Music	S: In this section here, in this part. (student verbal feedback on music: providing information on musical structure)	Case study A lesson 1
	T: For example, I wanted that we could do until here, […] until that first cadence. (teacher verbal feedback on music: giving direction on musical structure)	Case study A lesson 2
	T: You cannot test the opening [of the piece] […] it is sounding like you are testing it (teacher verbal feedback on music: providing information on musical structure)	Case study B lesson 2
	T: Can we repeat the beginning again? (teacher verbal feedback on music: giving directions on musical structure)	Case study B lesson 1
	T: But when you go to the fifth bar […] which is what happens here, (teacher verbal feedback on music: providing information on musical structure)	Case study C lesson 1
Performance	T: Because sometimes you… The silences, I don't know if you can perceive […] you shorten a bit, right, some silences. (teacher verbal feedback on performance: providing information on rhythmic accuracy)	Case study A lesson1
	T: Yeah, because it is clear that you hold the […] bottom note and this one, and this one [you hold] less (teacher verbal feedback on performance: providing information on articulation)	Case study A lesson 1
	T: I think I would do with the fourth [finger] […] I always thought the fourth [finger] was better […] than the third [finger], and the second [finger] (teacher verbal feedback on performance: providing information on fingering)	Case study B lesson 2
	T: And… an exact pause […] That's it. And do not change the rhythm, right. […] [T counting] […] [T saying tatata] (teacher verbal feedback on performance: giving directions on rhythmic accuracy)	Case study C lesson 1
Technology	T: Then here there is a red colour much more […] but here […] then, it comes back to the green colour. (teacher verbal feedback on technology: providing information on MIDI parameters)	Case study A lesson 1
	S: Yeah, you can see that this was tenser, this got darker […] and here it came back lighter […] but there are some details that you can see […] there are some changes, this you can see. (student verbal feedback on technology: providing information on MIDI parameters)	Case study A lesson 1
	T: So, could you put this playback now whilst he plays the left hand at the same time? (teacher verbal feedback on technology: giving directions on MIDI recording version)	Case study A lesson 2
	T: Let's listen to the beginning for you to realize this? […] Come on, let's see. […] Let's listen to it again, … (teacher verbal feedback on technology: giving direction on MIDI recording version)	Case study B lesson 2
	S: These notes [MIDI notes] had to be [should have been] longer. (student verbal feedback on technology: providing information on MIDI parameters)	Case study B lesson 2
	T: You can put, for example, the first [recording version], only the first part, from the very first time that he played, until there… (teacher verbal feedback on technology: giving directions on MIDI recording version)	Case study C lesson 1

Key: T represents teachers and S represents students

Table 6.7 Examples of non-verbal feedback on music, performance, and technology delivered by teacher and student per case study and lesson

Musical performance parameters	Picture from the video shot	Examples of non-verbal feedback	Case study and lesson
Music		Student non-verbal feedback on music (pointing to the music score for music structure)	Case study C lesson 2
		Teacher non-verbal feedback on music (pointing to the music score for music structure)	Case study C lesson 1
Performance		Teacher non-verbal feedback on performance (touching student shoulder for motor control issues)	Case study C lesson 1
		Teacher non-verbal feedback on performance (gestures for phrasing)	Case study B lesson 1
		Teacher non-verbal feedback on performance (gestures for motor control issues)	Case study B lesson 2
		Student non-verbal feedback on performance (gestures - left hand - for motor control issues, i.e. playing on the lap / mute playing)	Case study A lesson 1
		Teacher non-verbal feedback on performance (playing for harmony and tonality)	Case study A lesson 2
		Student non-verbal feedback on performance (touching for motor control issues, such as placing hands on the piano but not playing)	Case study A lesson 1
Technology		Student non-verbal feedback on technology (pointing to the computer screen for MIDI parameters)	Case study A lesson 2
		Teacher non-verbal feedback on technology (pointing to the computer screen for MIDI parameters)	Case study A lesson 2

Alongside specific verbal and non-verbal feedback across case studies, teacher general feedback was a sub-category of talk, since talk incorporated the sum of all verbal behaviours (see Appendix 7). General teacher feedback, in contrast to specific verbal and non-verbal feedback, is delivered only in terms of positive, negative or ambiguous feedback. General teacher feedback gives students an idea of whether their performance went well or was less successful, expressed through positive or negative feedback, respectively. At other times it is difficult to gauge what the teacher wanted to convey as the recorded evidence appears ambiguous. The investigation of general feedback adds understanding to the context of each case study, enabling the differences and similarities between cases to be seen more clearly. Examples of the three forms of general teacher feedback—positive, negative and ambiguous—which were provided by the teacher in each case study are illustrated in Table 6.8. Overall, relatively little time was observed to be spent in the provision of general feedback.

Table 6.8 Examples of general teacher feedback delivered in each case study

General feedback	Examples
Positive	T: It really improved, right? (teacher C, lesson 2)
	T: I think you really cared enough. (teacher B, lesson 2)
	T: Okay… is better… The Sonata is going well (teacher C, lesson 1)
	T: That's the idea. (teacher C, lesson 2)
	T: Congratulations. It improved a lot. (teacher C, lesson 2)
Negative	T: No, no, no. (teacher B, lesson 2)
	T: Yes. It's a little… it's a little awkward, still. (teacher C, lesson 1)
	T: No… no… no… no. (teacher C, lesson 1)
Ambiguous	T: Well… It didn’t sound bad here. (teacher A, lesson 1)
	T: It doesn’t make sense, [name of student C]. (teacher C, lesson)

Table 6.9 General teacher feedback time (%) and frequency (%) in lessons 1 and 2, and mean values, per case study

Case study		General feedback	
		Time (%)	Frequency (%)
A	Lesson 1	0	0
	Lesson 2	0	3
	Mean	0	1
B	Lesson 1	2	10
	Lesson 2	2	10
	Mean	2	10
C	Lesson 1	2	2
	Lesson 2	3	3
	Mean	3	3
Mean over six lessons		2	5

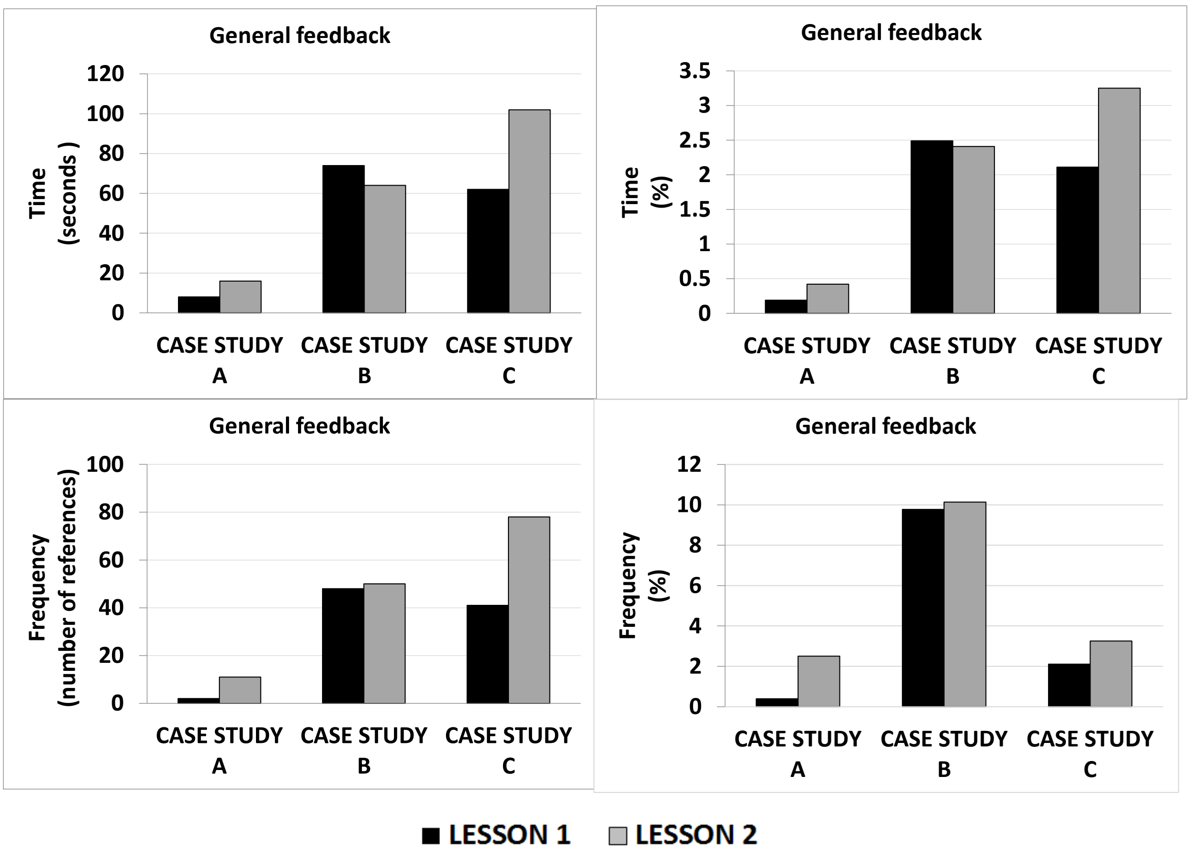


Figure 6.8 Time spent (seconds and %) and frequency (number of references and %) on general teacher feedback per case study lesson

Table 6.9 shows percentages of time and frequency for the sum of general teacher feedback types, positive, negative and ambiguous, and mean values over lessons per case study and across the six lessons. Figure 6.8 shows distribution of time and frequency on general feedback delivered by the teacher per case study. The time perspective is given in seconds and percentages, while frequency perspective is shown in number of references and respective percentages. The average time spent on general teacher feedback was greater for teachers in case studies B (*M* = 2%) and C (*M* = 3%), while for teacher A general feedback was virtually nil (*M* = 0%). General feedback time was consistent in case studies A and B while it increased in case study C, ranging from 2% to 3% between lessons 1 and 2. General feedback in case study B was more frequent (*M* = 10%) than in other case studies A (*M* = 1%) and C (*M* = 3%), and also more consistent across lessons. This evidence might indicate that general feedback is more observed in master-apprenticeship teaching styles than in collaborative teaching styles. Although specific rather than general feedback was the focus of this study, general feedback was reported upon because it provides the overall context of the amount of feedback per case study. This study focused on specific feedback as this is directly related to the musical performance parameters of music, performance and technology, rather than to general teacher comments on student performance outcomes, be this of approval, disapproval, or ambiguity.

6.6 Summary

This chapter reported findings from video qualitative data analyses (QDA) for verbal and non-verbal feedback types in relation to three selected musical performance parameters: music, performance and technology. The focus on feedback involved consideration of the overall talk, playing and feedback per case study (Table 6.1 and Figure 6.4) and per participant (Table 6.3 and Figure 6.5), then of verbal and non-verbal feedback (Tables 6.4 to 6.8 and Figures 6.6 to 6.7). General feedback was also reported to provide a contextual background for this study on feedback (Table 6.9 and Figure 6.8).

Talk, playing and verbal and non-verbal feedback were analysed in all three case studies. The time spent on talk predominated in all case studies. Feedback was stable across case studies. Playing was observed much less in case study A. When considering teacher and student, most of the time was devoted to teacher talk, student playing and teacher feedback. A minimal length of time was spent on student talk, teacher playing and student feedback. A dependent relationship was found between teacher feedback and student playing. Teacher playing in case study C was substantially higher in comparison with other case studies. Teacher C was modelling the desired musical behaviour as a form of pedagogical practice by using playing as a form of non-verbal feedback.

Although feedback was predominantly delivered by the teacher, students also provided feedback in subtle ways. This evidence suggests a potential route for self-assessment of students in lessons when technology is used, and could help to move them towards a more independent and autonomous learning process. Verbal and non-verbal feedback was linked to three areas: music, in terms of music structure, performance, such as dynamics, articulation, and rhythmic and melodic accuracy, and technology, in terms of MIDI parameters. Teacher verbal feedback which provided information on performance was the most observed type of verbal feedback. Teacher verbal feedback which provided information on technology was the second most observed in case studies A and B, and music in case study C. In case study C, teacher verbal feedback on technology was minimal. Teacher non-verbal feedback on performance was also the most observed type of non-verbal feedback across case studies. Teacher non-verbal feedback on music and technology was biased across case studies. This evidence suggests that teacher non-verbal feedback was particular to each case study and related to the individual pedagogical styles of each teacher. Teacher non-verbal feedback was also related closely to the individual differences and needs of the student, as well as to the specific repertoire. General teacher feedback was present across all three case studies in terms of positive, negative, and ambiguous statements, demonstrated when teachers made a judgemental comment on student performance outcomes. General teacher feedback was also observed more in case studies B and C than in case study A, suggesting it might be a characteristic of master-apprenticeship rather than collaborative teaching styles. Chapter 7 addresses the technology-mediated feedback use across case studies.

7 Video QDA: technology-mediated feedback use across three case studies

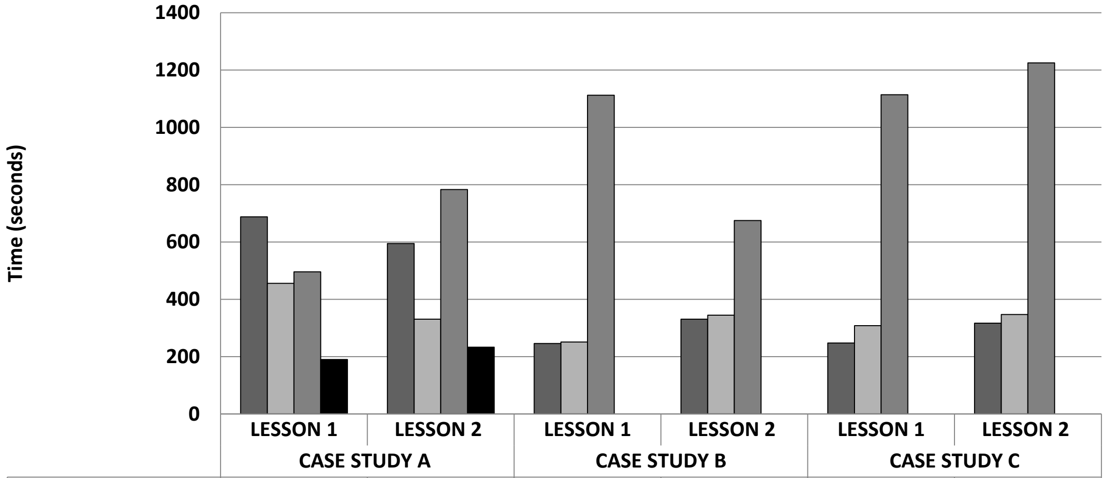
7.1 Introduction

In this chapter, findings from video QDA are reported for the pedagogical use of technology-mediated feedback within each of the three case studies, and then across them. In order to analyse the six videoed piano lessons for this purpose, a perspective complementary to video QDA on verbal and non-verbal feedback (see Chapter 6) was taken. Analyses of the application of technology-mediated feedback were conducted by examining the coding stripes of themes from the previous video QDA. The analytical themes were based on the technology-related verbal and non-verbal behaviours of teacher and student participants as well as my researcher behaviours. My researcher behaviours involved operating the technology: recording, playing back, screen switching, and manipulating the DAW software. Recording and playing back are self-explanatory behaviours in a normal mode. Screen switching involved shifting the computer screen in a silent mode. Manipulating involved my researcher behaviours, such as saving the DAW project data and looking for a specific part of the music in its screen representation. The videos were directly coded on the timeline of the CAQDA navigation interface, according to the coding stripes from previous video QDA. This complementary video QDA permitted me to evaluate the pedagogical use of technology-mediated feedback in example HE piano studios in terms of six variables: non-use of technology, use of technology in real-time, post-hoc use, metronome use, silent post-hoc use, and post-hoc use at a slower tempo. An overview of my researcher behaviours across the three case studies, and on the pedagogical use of technology-mediated feedback will be reported in the next sections.

Six variables in this study were seen to influence technology-mediated feedback in HE piano lessons. The first, non-use of technology, related to lessons where no visual feedback was available. This happened when there was no activity on the computer screen and the participants were at the beginning of their lessons. Second, real-time feedback use was examined when either teacher or student had a clear lesson focus for its use, and were looking at the computer screen whilst playing the digital piano, and I was recording the performance-related data on the DAW software. Third, post-hoc feedback was used when the playing back of performance-related data on the DAW software was requested either by the teacher and student pair, or suggested by myself as a lesson focus which accorded to their learning priorities or learning needs. Fourth, metronome use was coded for the moments when the metronome was set. Fifth, silent post-hoc feedback described the moments where I screen switched in a silent mode. This was when I moved the computer screen by scrolling up and down, and from left to right, while the teacher and student pair looked at the frozen computer screen in relation to their particular lesson focus. Finally, post-hoc feedback at a slower tempo was used when I played back the performance-related data at half the original tempo with a clear lesson focus, either when requested to do so by the teacher and student pair or suggested by myself. The application of technology-mediated feedback in each case study and across case studies is discussed in this chapter.

7.2 Overview of researcher technology behaviours

The previous chapter addressed the research focus on verbal and non-verbal feedback which was related to music, performance and technology areas by teacher and student pairs within each of the three case studies. The chapter described and discussed thematic analyses of teacher and student verbal and non-verbal behaviours, and music performance parameters which were observed through the video QDA in NVivo10 (see Appendices 7, 8, and 9). However, my verbal and non-verbal behaviours were also coded (see Appendices 7 and 8 for researcher behaviours) as they were related to the role of the researcher as a facilitator in operating the technology-mediated feedback in each case study.



	CASE STUDY A LESSON 1	CASE STUDY A LESSON 2	CASE STUDY B LESSON 1	CASE STUDY B LESSON 2	CASE STUDY C LESSON 1	CASE STUDY C LESSON 2
PLAYING BACK	688	595	246	331	248	317
MANIPULATING	456	331	251	345	308	347
RECORDING	496	783	1112	675	1114	1225
SCREEN SWITCHING	190	233	0	0	0	0

Figure 7.1 Non-verbal researcher technology behaviours across case studies

Figure 7.1 illustrates the total amount of time in seconds spent on four main observed non-verbal researcher behaviours: playing back, manipulating the DAW software, recording, and screen switching. Playing back relates to the time at which I was playing back the recorded performance-related data that had been generated when student or teacher had played their chosen piece at the digital piano. Manipulating is linked to the moments when I was operating the technology, for instance by saving the project or looking for a specific musical excerpt on the computer screen. Recording encompasses the points at which I was recording the performance-related data generated when student or teacher was playing the chosen piece at the digital piano. These recording moments mainly coincided with the participant playing moments; however they are not necessarily of the same time length, as not all playing moments were recorded. Finally, screen switching involves the moments when I was moving the computer screen, by scrolling up and down, and from left to right, in silent mode.

Overall, the patterns of technology-mediated feedback use are consistent within each case study. I spent considerable time on recording the performance-related data across the three case studies on the DAW software while the student or teacher was playing the digital piano. In case study A, the time spent on playing back the recorded performance-related data was greater than in the other case studies. In contrast, time spent manipulating the technology and playing back the recorded performance related-data was stable in case studies B and C. While the data shown in Figure 7.1 might not indicate effective or conscious technology-mediated feedback use, they do provide information about the overall patterns of my non-verbal behaviours which mediated the technology in each case study. Previous video QDA of my researcher behaviours guided the video QDA of technology-mediated feedback use over time. This second use of video QDA complemented earlier video source coding since the rereading of those coding stripes for participant and researcher technology-related behaviours was required.

7.3 Technology-mediated feedback use in case study A

The pedagogical use of technology-mediated feedback was investigated in case study A. The video QDA of the technology-mediated feedback use over time was conducted by coding themes on the video itself at the timeline on the CAQDA software navigation interface. The distributions of technology-mediated feedback use over time in case study A for both lessons are shown in Table 7.1 and Figure 7.2.

Table 7.1 shows the specific moments in each lesson which demonstrate different uses of technology-mediated feedback and the corresponding musical performance parameters which were worked on during the technology use. Figure 7.2 illustrates coding stripes from the CAQDA interface of the video QDA of technology-mediated feedback use which was used over time in both lessons in case study A. Figure 7.2 gives visual information on the pedagogical use of technology-mediated feedback in case study A. Table 7.1 shows the moments at which types of technology-mediated feedback in case study A were used over time in both lessons. Real-time feedback was excluded as it seemed to be used in a very subtle way by the student and did not seem to have been used by the teacher and student pair. The purposes for using technology-mediated feedback were cross-checked against the previous thematic analyses in the transcription rows. This procedure involved identifying the musical performance parameters, in terms of music, performance, and technology, which were found within the moments where technology was used in lessons.

Table 7.1 Pedagogical uses of technology-mediated feedback over time in case study A

CASE STUDY A LESSON 1				
Timeline order	TECHNOLOGY-MEDIATED FEEDBACK USE	Moment on the time line	Partial time coverage (%)	Overall purposes (lesson foci)
1	NO VISUAL FEEDBACK	0:00 - 7:05	9.62%	N/A
2	POST HOC	14:45 - 24:04	12.64%	Performance, technology
3	SILENT POST HOC	25:35 - 26:45	1.58%	Music, performance, technology
4	SILENT POST HOC	26:45 - 35:18	11.61%	Music, performance, technology
5	POST HOC	36:00 - 42:41	9.08%	Music, performance, technology
6	SILENT POST HOC	1:05:09 - 1:05:52	0.97%	Music, performance, technology
7	POST HOC	1:05:55 - 1:07:23	3.04%	Performance, technology
CASE STUDY A LESSON 2				
Timeline order	TECHNOLOGY-MEDIATED FEEDBACK USE	Moment on the time line	Partial time coverage (%)	Overall purposes (lesson foci)
1	NO VISUAL FEEDBACK	0:00 - 3:02	4.77%	N/A
2	POST HOC	16:40 - 24:07	11.64%	Music, performance, technology
3	POST HOC	32:48 - 35:25	4.09%	Music, performance, technology
4	SILENT POST HOC	35:25 - 40:59	8.71%	Music, performance, technology
5	METRONOME	41:55 - 46:01	6.41%	Performance
6	SILENT POST HOC	46:16 - 46:46	0.79%	Music, performance, technology
7	POST HOC	46:46 - 50:00	5.05%	Music, performance, technology
8	METRONOME	47:22 - 48:20	1.51%	Performance
9	METRONOME	48:43 - 49:17	0.89%	Music, performance
10	SILENT POST HOC	52:07 - 53:27	2.09%	Music, performance, technology
11	SILENT POST HOC	59:04 - 1:00:24	2.11%	Music, performance, technology

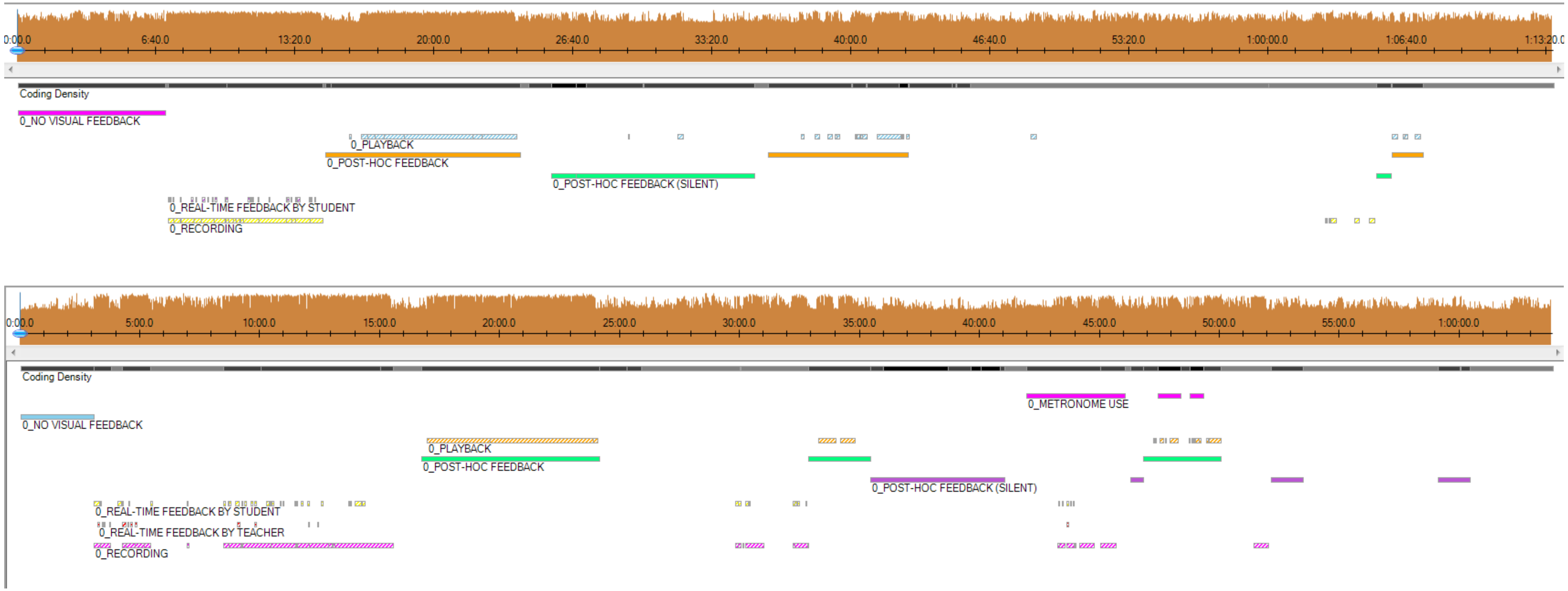


Figure 7.2 CAQDA screenshot excerpts showing video QDA of technology-mediated feedback use in minutes/seconds during lessons 1 (top) and 2 (bottom) in case study A

The timelines shown in Figure 7.2 permitted examination of the following five types of technology-mediated feedback uses over time in case study A: no technology-mediated feedback; real-time feedback; post-hoc feedback at the original tempo; metronome use; and silent post-hoc feedback. Technology use in real-time feedback is absent from Table 7.1 but appears in the timeline in Figure 7.2. This anomaly is accounted for by student only use as an individual experience during the lessons rather than as a shared experience between teacher and student.

No technology-mediated feedback use was found at the beginning of lessons when there was no activity on the computer screen as visual feedback. Real-time feedback seemed to have been used in a segmented and subtle way by student A while playing the piece to meet individual learning needs. Real-time feedback enabled student A to visualize what was happening on the computer screen while trying to improve a particular aspect of performance, such as the left hand articulation of the Alberti bass. Although teacher A looked at the computer screen in real-time much more in lesson 2 than in lesson 1, there is evidence through video QDA that the teacher was evaluating whether or not the use of technology-mediated feedback in real-time was interfering with student performance. The use of technology in real-time feedback seemed to have disturbed the attention of the teacher rather than that of the student. This possibility could account for why the teacher seemed to have avoided looking at the computer screen in real-time.

The metronome was used in lesson 2. The aims were twofold: to achieve tempo synchronization while, at the same time, working on dynamic balance in a chosen piano piece. Thus, the first aim sought to synchronize the tempo of the right- and left-hand of the student playing. The second aim was to evaluate the dynamic balance between both hands. An attempt to achieve these aims was made by playing back a pre-recorded right-hand while recording the left-hand of student playing when using DAW software. However, for technical reasons the recording of a left-hand playing over the playing back of a pre-recorded right-hand playing was unsuccessful. Since the dynamic balance was the lesson focus, an alternative was to record the teacher playing the right hand and the student playing the left hand simultaneously, and to compare the visual feedback of both participant performances.

Post-hoc feedback, in terms of normal mode, was used in case study A in both lessons. For example, immediately after student performance the whole piece was played back without interruption at the original tempo. Additionally, post-hoc feedback was used on six occasions, three times in each lesson. It involved checking the articulation of the left hand, rhythmic accuracy for silences between music sections in the piece, and dynamic contrast.

Silent post-hoc feedback was perhaps the main feature of technology-mediated feedback use in case study A. Use of silent post-hoc feedback mainly occurred when I screen switched by scrolling up and down, and from left to right, or used a frozen computer screen while both teacher and student participants were looking at the computer screen with a clear lesson focus in mind. Silent post-hoc feedback was used by participants to discuss musical performance parameters according to their perceptions of what they saw on the computer screen and how these could help improve student performance. Silent post-hoc feedback seemed to be used on two occasions in lesson 1 and on four occasions in lesson 2. In lesson 1, the main purposes of using silent post-hoc feedback were to check the dynamic contrast and to explore pedalling responses through MIDI parameters. Particular attention was paid to MIDI notes colours and the pressing down and releasing of pedals and the pedal level. In lesson 2, the purpose of using silent post-hoc feedback was to investigate the dynamic balance between right and left hands and to see the correspondent velocity key numbers for each played MIDI note of a chosen musical excerpt.

7.4 Technology-mediated feedback use in case study B

The pedagogical use of technology-mediated feedback was also examined in case study B. As in case study A, the video QDA of technology-mediated feedback use over time was conducted by coding themes shown on the video itself and locating them on the timeline in the CAQDA software navigation interface. The distribution of technology-mediated feedback use over time in lessons 1 and 2 for case study B is shown in Table 7.2 and in Figure 7.3. Table 7.2 identifies the moments of different uses of technology-mediated feedback in lessons 1 and 2, and the corresponding musical performance parameters linked to them. Figure 7.3 shows example coding stripes alongside the timeline extracted from the interface of the CAQDA software. The following three types of technology-mediated feedback use were identified through video QDA in case study B: no technology-mediated feedback, real-time feedback, and post-hoc feedback at the original tempo.

No technology-mediated feedback was observed when lessons started and the computer screen was not showing any form of visual feedback. Real-time feedback appeared to be used more by the teacher than the student in case study B. This is in contrast to case study A, where real-time feedback was used more by the student to help meet their individual needs. Teacher B seemed to use real-time feedback to connect with potential improvements to the student performance. Teacher B guidance was fundamental in helping student B to use real-time feedback meaningfully. The use of real-time feedback was clearly observed by myself since teacher B used it in the piano lessons. Real-time feedback was used for a clear lesson focus by teacher B during two short instances late in lesson 1 and on three occasions in lesson 2. Overall, feedback was used to check articulation, and melodic accuracy.

Table 7.2 Pedagogical uses of technology-mediated feedback over time in case study B

CASE STUDY B LESSON 1				
Timeline order	TECHNOLOGY-MEDIATED FEEDBACK USE	Moment on the time line	Partial time coverage (%)	Overall purposes (lesson foci)
1	NO VISUAL FEEDBACK	0:00 - 8:20	16.96%	N/A
2	POST-HOC	15:39 - 19:41	8.22%	Music, performance, technology
3	POST-HOC	22:10 - 22:43	1.36%	Music, performance, technology
4	POST-HOC	29:02 - 31:38	5.29%	Music, performance, technology
5	POST-HOC	31:41 - 34:06	4.89%	Music, performance, technology
6	POST-HOC	37:25 - 38:31	2.23%	Music, performance, technology
7	REAL-TIME	39:48 - 40:36	1.62%	Music, performance, technology
8	REAL-TIME	43:30 - 43:37	0.26%	Technology
CASE STUDY B LESSON 2				
Timeline order	TECHNOLOGY-MEDIATED FEEDBACK USE	Moment on the time line	Partial time coverage (%)	Overall purposes (lesson foci)
1	NO VISUAL FEEDBACK	0:00 - 3:49	8.56%	N/A
2	POST-HOC	10:39 - 12:37	4.40%	Music, performance, technology
3	REAL-TIME	13:06 - 14:39	3.50%	Performance, technology
4	POST-HOC	17:25 - 23:10	12.88%	Music, performance, technology
5	NO VISUAL FEEDBACK	24:17 - 26:00	3.83%	N/A
6	REAL-TIME	26:00 - 27:26	5.88%	Music, performance, technology
7	POST-HOC	35:35 - 37:14	3.70%	Performance, technology
8	REAL-TIME	37:14 - 38:28	2.76%	Music, performance, technology
9	POST-HOC	40:55 - 43:13	5.14%	Music, performance, technology

Figure 7.3 CAQDA screenshot example excerpts showing video QDA of technology-mediated feedback use in minutes/seconds during lessons 1 (top) and 2 (bottom) in case study B

Post-hoc feedback was used by both teacher and student in case study B. In each lesson, post-hoc feedback was used in the original tempo in four instances, where it seemed to function as auditory feedback to compare the recorded performance-related data of two similar or equivalent musical sections. However, the extent to which post-hoc feedback was used for auditory feedback only, or for both visual and auditory feedback, is unclear. Post-hoc feedback could show not only musical performance parameters that needed to be improved but also those which went well.

7.5 Technology-mediated feedback use in case study C

The pedagogical use of technology-mediated feedback was also examined in case study C. As in case studies A and B, the video QDA of technology-mediated feedback use over time was conducted by coding themes shown on the video itself and locating them on the timeline in the CAQDA software navigation interface. The distribution of technology-mediated feedback use over time in lessons 1 and 2 for case study C is illustrated in Table 7.3 and Figure 7.4. Table 7.3 shows different moments throughout the lessons when different technology-mediated pedagogical approaches were used and linked to musical performance parameters. Figure 7.4 shows technology-mediated feedback use over time in both lessons in case study C through the coding stripes from the CAQDA software interface of this video QDA.

The three types of technology-mediated feedback use found in case study C were: no technology-mediated feedback; post-hoc feedback in the original tempo; and post-hoc feedback at a slower tempo. There was no technology-mediated feedback use at the beginning of lessons since the computer screen was not showing any visual feedback. Real-time feedback did not seem to be used in case study C by either the student to meet their individual learning needs or by the teacher to guide the student in terms of a clear lesson focus. Teacher C appeared to show no awareness of performance recording moments as demonstrated by the following statement to me: “when you need, you interrupt me” (lesson 1). Consequently, it can be argued that the teacher seemed unaware of the visualization available on the computer screen in real-time while recordings of the performance-related data were being made. This might also mean that neither teacher nor student used the real-time feedback with a clear lesson focus in case study C.

Table 7.3 Pedagogical uses of technology-mediated feedback over time in case study C

CASE STUDY C LESSON 1				
Timeline order	TECHNOLOGY-MEDIATED FEEDBACK USE	Moment on the time line	Partial time coverage (%)	Overall purposes (lesson foci)
1	NO VISUAL FEEDBACK	0:00 - 3:59	8.10%	N/A
2	NO VISUAL FEEDBACK	15:09 - 15:33	0.82%	N/A
3	POST-HOC	19:56 - 22:32	5.28%	Music, performance, technology
4	POST-HOC	31:35 - 35:07	7.16%	Music, performance, technology
5	POST-HOC	41:51 - 44:15	4.87%	Music, performance, technology
6	POST-HOC (SLOWER)	46:08 - 47:30	2.76%	Music, technology
CASE STUDY C LESSON 2				
Timeline order	TECHNOLOGY-MEDIATED FEEDBACK USE	Moment on the time line	Partial time coverage (%)	Overall purposes (lesson foci)
1	NO VISUAL FEEDBACK	0:00 - 1:11	2.26%	N/A
2	POST-HOC	8:37 - 10:30	3.59%	Music, performance, technology
3	POST-HOC	18:09 - 21:34	6.51%	Music, performance, technology
4	POST-HOC	28:24 - 29:34	2.22%	Music, performance, technology
5	POST-HOC (SLOWER)	29:34 - 32:36	5.79%	Music, performance, technology
6	POST-HOC	37:13 - 38:16	2.02%	Music, performance, technology
7	POST-HOC (SLOWER)	38:16 - 39:24	2.17%	Music, performance, technology
8	POST-HOC	44:36 - 45:19	1.37%	Music, performance, technology

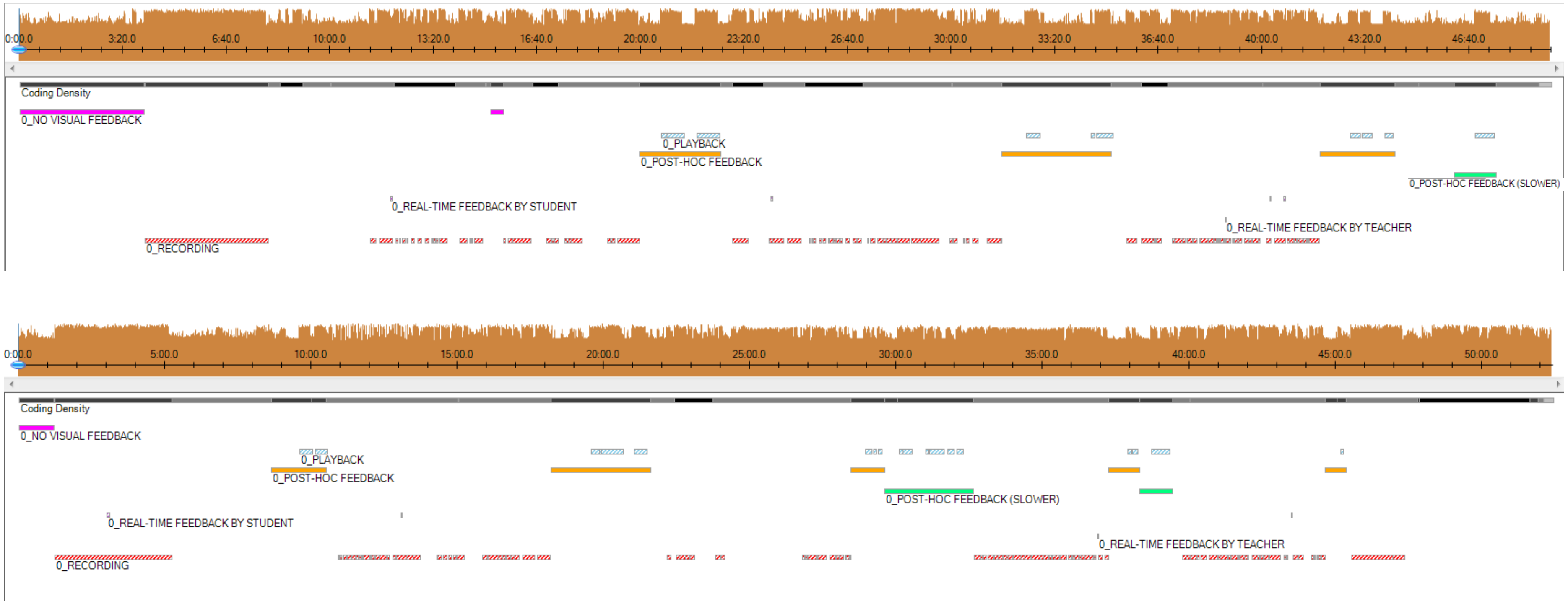


Figure 7.4 CAQDA screenshot example excerpts showing video QDA of technology-mediated feedback use in minutes/seconds during lessons 1 (top) and 2 (bottom) in case study C

Post-hoc feedback seemed to be the preferred type of technology-mediated feedback use for the pair in case study C, and it was used on three occasions in lesson 1 and on five occasions in lesson 2. However, these instances of post-hoc feedback use were simply related to the moments when I was asked to play back a recorded version of a performance, or when I suggested doing so. Post-hoc feedback played at either the original or slower tempo enabled the teacher and student pair to listen back to the recorded performance-related data at the same time as looking at the visualization on the computer screen.

Post-hoc feedback in the original tempo was primarily used to compare different performance-related data recording versions or MIDI data recording versions of student playing which were made before and after verbal or non-verbal teacher feedback. Post-hoc feedback was used secondarily to listen back twice to the same recorded version for different purposes. The first replaying focused on dynamics and technique, while the second replaying focused on the articulation of the octave attack, dynamics between hands, and technique regarding the left hand or right hand, and octaves. Finally, auditory post-hoc feedback was also used to compare recorded performance-related data by both teacher and student. The teacher might have used post-hoc feedback in order to make the student aware of the musical performance parameters requiring improvement in selected musical excerpts of the chosen piece.

Post-hoc feedback at a slower tempo, played at half the original tempo, was initially suggested by myself late in lesson 1; it was also requested by the teacher in lesson 2. Post-hoc feedback at a slower tempo was mostly required by the teacher for the purposes of making the student aware of rhythmic (in)accuracy and dynamics. Recordings of performance-related data by the teacher and student were compared with each other using post-hoc feedback at a slower tempo.

7.6 Overall technology-mediated feedback use across case studies

Video QDA of technology-mediated feedback use in example HE piano studio settings reveals alternative pedagogical approaches being applied. The application of technology-mediated feedback varied in terms of: timing, such as real-time or post-hoc; mode, in terms of silent or normal; and tempo, original or slower. The pedagogical use of technology-mediated feedback seemed related to four approaches: real-time feedback use, post-hoc feedback use in the original tempo, silent post-hoc feedback use, and post-hoc feedback use at a slower tempo. The extent to which the nature of technology-mediated feedback use was focused on either auditory or visual feedback will be discussed further in Chapters 8 and 9.

The most commonly observed type of technology-mediated feedback use across the three case studies was post-hoc feedback in the original tempo. This means that I was requested by teachers and their students to playback recorded performance-related data so that they could just listen to a recording of the focus performance. Post-hoc feedback enabled teachers and their students to listen to their recordings instead of multitasking by listening and playing their chosen pieces simultaneously. However, participants in each case study had preferences for the use of technology in their own particular way. For example, silent post-hoc feedback was used in case study A, real-time feedback was used in case study B, and post-hoc feedback at a slower tempo was used in case study C.

Video QDA of technology-mediated feedback also revealed musical performance parameters which seemed to have been worked on during the two lessons in each case study relating to music, performance, technology. Multiple layers of musical performance parameters that were observed and which were likely to be related to each type of technology-mediated feedback use are illustrated in Table 7.4. Note: the use or potential use of technology-mediated feedback for improvement of particular musical performance parameters with a clear lesson focus in student performance, such as dynamics and articulation, will be evidenced in Chapter 9.

Table 7.4 shows that each of the three music performance parameters, music, performance and technology, could have been worked on in the example HE piano lessons by using any of the four pedagogical approaches to technology-mediated feedback, namely real-time, post-hoc in the original tempo, silent post-hoc, and post-hoc at a slower tempo. Apart from the common use of post-hoc feedback in the original tempo, the pattern of pedagogical approaches varies across case studies.

Table 7.4 Types of technology-mediated feedback use according to aspects of music, performance, and technology per case study (generated by combining Tables 7.1, 7.2, and 7.3)

Musical performance parameters		Technology-mediated feedback use per case study			
		Real-time	Post-hoc	Silent post-hoc	Slower post-hoc
Music	Harmony and tonality		B	A	
	Music structure	B	A B C	A	C
Performance	Articulation	B	B C		
	Dynamics	B	B C	A	
	Fingering	B	B		
	Melodic accuracy	B	C		
	Metaphors	B	A B	A	
	Motor control issues	B	A B		C
	Other parameters		A B	A	C
	Pedalling	B	A B	A	
	Phrasing		A B C	A	
	Rhythmic accuracy		A B C	A	C
	Technique	B	A B C	A	
	Tempo	B	A B C		C
Technology	Digital piano		B		
	MIDI parameters	B	A B C	A	C
	MIDI recording version	B	A B C	A	C

The use of post-hoc feedback might be helpful not only for the student but also for the teacher. For the teacher, post-hoc feedback might be a particularly useful tool for self-evaluating their own feedback efficacy. For instance, the teacher could play back different student performance versions of a piece in order to gauge student responses to the teaching. The teacher can also evaluate the effectiveness of the feedback given during the lesson by listening back to different recorded versions of student performances, and comparing one with another.

For the student, post-hoc feedback can also be beneficial such as when listening back to their own playing, reflecting on what needs to be improved and assessing what went well in their performance, together with a consideration of teacher feedback. Post-hoc feedback might be beneficial because the student has the opportunity to listen to performance-related data and reflect on their own performance outcomes separately from playing their chosen pieces. In addition, there are additional types of feedback which can benefit students apart from relying on their teacher modelling exemplar performances or imitating student performance in exaggerated style, as are commonly noticed in conventional piano lessons. Thus, post-hoc feedback might improve the students' awareness of their own performance and thus enhance learning. Listening to recorded performances in combination with verbal and non-verbal teacher feedback during piano lessons might bring a clear lesson focus on how to support student learning priorities.

The application of technology-mediated feedback seemed to differ mainly because of the individual differences, including individual biographies, and preferences of participants in the three case studies, and the particular ways in which participants engaged with the technology-mediated feedback, either through auditory or visual feedback. Individual differences included participant age, gender, piano learning and teaching experience time, even though the focus of this study is not on these variables. Further research into these variables would be worthwhile in order to see how they impact on technology-mediated feedback use. In this study, the chosen musical repertoire, length of lesson, and also the interval period between the two lessons across case studies differed slightly but they did not seem to have a great impact on the findings. However, technology-mediated feedback use in this study are context specific to one-to-one piano learning and teaching, working on a weekly basis on classical sonatas.

7.7 Summary

Video QDA of technology-mediated feedback use was achieved by coding video content directly onto the CAQDA timeline. This video QDA indicate the range of pedagogical approaches in which technology-mediated feedback was applied over time across three case studies in HE piano studios. While four strands of technology-mediated feedback use were observed, post-hoc feedback was the most commonly adopted across all three example case studies. Post-hoc feedback occurred mainly when teacher and student pairs requested the playing of performance-related data recordings. The use of post-hoc feedback can benefit students since they can self-assess their performances without playing at the same time. This type of technology-mediated feedback may also benefit teachers, who can self-evaluate the effectiveness of their feedback by comparing several versions of student performance outcomes.

Different uses of technology-mediated feedback were also found across the case studies for silent post-hoc feedback as seen in case study A, real-time feedback as demonstrated in case study B, and post-hoc feedback at a slower tempo as illustrated by case study C. The application of real-time feedback was conducted while students were playing, and the use of silent post-hoc feedback and post-hoc feedback occurred when students were not playing. Although differences in pedagogical approaches across case studies were found, several musical performance parameters can be worked on by using technology-mediated feedback in the piano studio. The ways in which each case study engaged with technology-mediated feedback use, either as additional visual or auditory feedback, are discussed in Chapters 8 and 9 respectively.

8 Video QDA: findings in relation to additional auditory feedback across case studies

8.1 Introduction

This chapter offers an overview of the types of auditory feedback which occur when technology-mediated feedback is applied in HE piano studios. In order to address how different types of additional auditory feedback are used by teachers and students, microstructure analyses of their video-recorded musical behaviours were conducted in each of the two lessons per case study. Musical behaviours within lessons included musical practice, which describes the moments of the teacher or student playing, and listening back, which describes my moments as the researcher playing back recorded performance-related data generated by the teacher or student. Microstructure analyses were conducted in order to understand those aspects of musical behaviours in relation to the musical structure of the chosen memorised pieces which were not explained by the previous video QDA. The primary aim of the microstructure analyses was to examine these two participant musical behaviours in relation to the sections of the chosen musical piece which were worked on in each lesson, either by playing or listening back. The secondary aim was to identify the musical performance parameters related to these musical sections. Microstructure analyses showed the types of auditory feedback which were available to participants either in real-time or post-hoc in both lessons in relation to their chosen repertoire. Real-time auditory feedback was available when the teacher, or student, or both were playing the piano piece. Post-hoc auditory feedback was available whenever I was playing back the recorded performance-related data either at the original tempo or at a slower half tempo. This chapter also reports on auditory feedback and the musical performance parameters related to the musical sections worked on in each case study. The commentary enables a broader cross-case study perspective.

8.2 Auditory feedback use by participants

Investigation of participant use of auditory feedback in each case study lesson was conducted through microstructure analysis of musical behaviours through the SYMP software tool created by Demos and Chaffin (2009), available for download at http://musiclab.uconn.edu/introduction/. Musical behaviours are defined here as both the musical practice, which addresses moments of teacher or student playing, and listening back, which describes moments of playing back the recorded performance-related data generated by the teacher and student. Microstructure analyses of musical behaviours were conducted from the video data per lesson and case study. Initially, musical behaviours were transcribed with regard to the structure of each chosen piece. Musical behaviours were also transcribed with regard to which participant—teacher or student—generated the auditory feedback. Microstructure analyses of musical behaviour allowed for the examination of the auditory feedback available in lessons through a graph showing musical bars versus musical segments over time, and the musical performance parameters which were related to each bar by completing a performance cues matrix in the same SYMP software tool (see Appendix 11 for an example using SYMP software recorded on Excel spread sheets).

In this study, the microstructure analysis of musical behaviour using SYMP software generated a separate graph (see Appendix 12 for all graphs) and performance cues matrix (see Appendix 11 for an example) for each lesson per case study. The vertical axis shows in ascending order the number of uninterrupted musical segments which were actually played and/or which were listened to over time. The horizontal axis shows the total number of bars from the first to last of the chosen pieces. Figure 8.1 shows 88 musical segments from across the 74 bars which were worked on in case study A, lesson 2. Thus, Figure 8.1 visually represents the auditory feedback available throughout the lesson either in real-time (playing) or post-hoc (playing back).

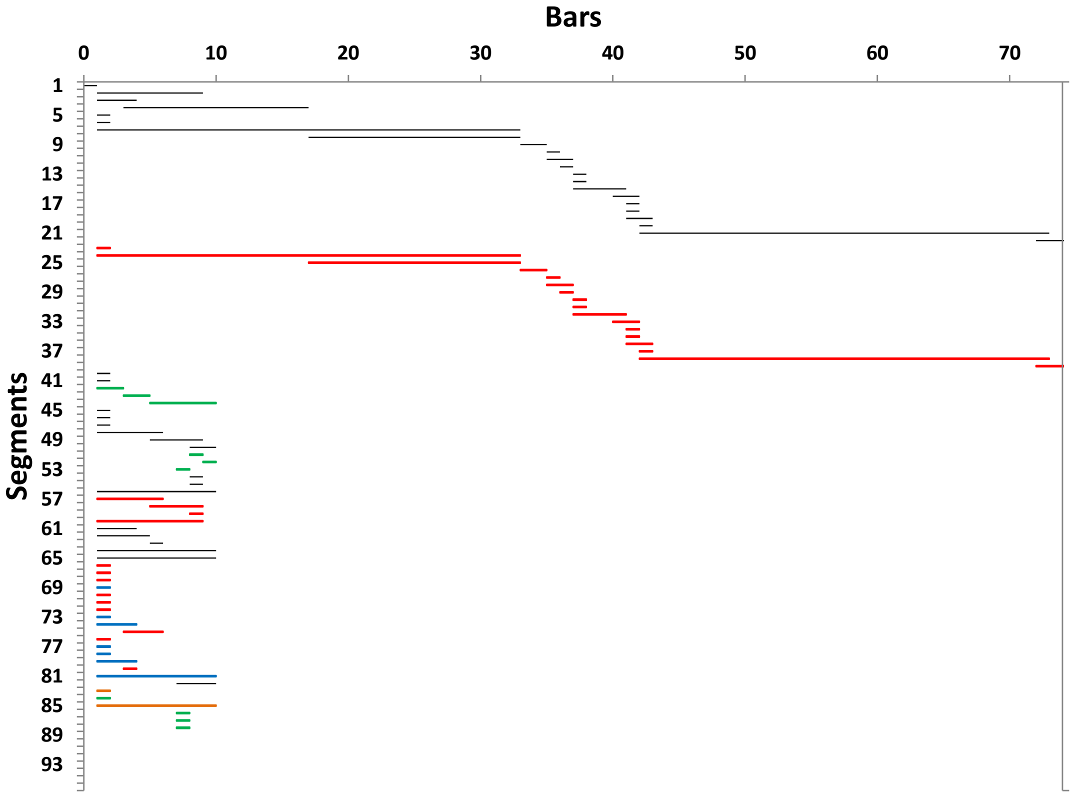


Figure 8.1 Microstructure analyses showing auditory feedback available in case study A, lesson 2, according to the musical structure of the chosen piece (Mozart Piano Sonata No. 16 in C major, K. 545)

Colour code: black—real-time auditory feedback by student; red—post-hoc auditory feedback by student; green—real-time auditory feedback by teacher; blue—a combination of real-time auditory feedback by student alongside post-hoc auditory feedback by student, and orange—real-time auditory feedback by the teacher playing alongside the student.

Auditory feedback was generated by performance or play back of performance-related data by either or both participants per lesson. Thus, auditory feedback was available whenever the student, teacher or both participants were playing, and whenever I was playing back the recorded performance-related data. In order to clarify who generated the auditory feedback, colour coding was used in the graphs. Across case studies a total of eight colour codes were used to differentiate between types of auditory feedback: real-time auditory feedback, by student, by teacher, and by the teacher alongside the student; post-hoc auditory feedback in the original tempo, by student or by teacher; post-hoc auditory feedback at a slower tempo, by student or by teacher; and a combination of real-time and post-hoc auditory feedback, such as playing alongside or over the play back of recorded performance-related data. The total number of bars correspondent to each chosen piece differed among case studies: 74, 162 and 144 in case studies A, B and C, respectively.

8.3 Real-time auditory feedback use by participants

When comparing the six SYMP generated graphs, student playing and teacher playing were found across all case studies and all lessons. Teacher playing alongside their respective student was found in case study A, lesson 2, case study B, lesson 1, and case study C, lessons 1 and 2 (see Appendix 12). Lessons usually opened with a student playing of the whole performance. Short and consecutive musical segments in each graph represent student practice. For example, playing and repeating may denote technically difficult passages or attempts at playing and trying to retrieve particular musical excerpts from memory.

The nature of real-time auditory feedback in case studies A and B are similar. While student playing predominated over teacher playing, a few segments revealed teacher playing alongside the student. Unlike case studies A and B, the nature of real-time auditory feedback in case study C shows more segments of teacher playing and instances of teacher playing alongside the student. In case study C, lessons 1 and 2, the teacher and student pair seemed to have worked intensively, exemplified by the many repetitions, with teacher playing to model or imitate student playing. There was also a significant increase in the number of musical segments by the teacher, from 237 in lesson 1 to 461 in lesson 2 (see Appendix 12), which indicates the increased dominance of teacher playing in lesson 2. In addition, the dominance of teacher C modelling is also revealed through a sequence of short musical excerpts which act as a reminder or "to do list" for the student as a lesson closure.

8.4 Post-hoc auditory feedback use by participants

Post-hoc auditory feedback was available whenever I played back recorded performance-related data generated by the performer participant, such as the student, teacher or both participants. Post-hoc auditory feedback could be listened back to in terms of the length of music excerpts such as the whole performance, or chosen excerpts. Post-hoc auditory feedback could also vary in terms of recording versions, since different performance-related data of the same excerpt by the same performer could be recorded on the technology system. Thus, post-hoc auditory feedback varied in three aspects: the performer, length of musical excerpt, and recording version. In addition, post-hoc auditory feedback could be used at the original tempo or at a slower half-tempo.

The nature of post-hoc auditory feedback across case studies was similar to the listening back of student recorded performances, but differed in relation to the playback of teacher recorded performances and playing back at a slower tempo. In both lessons in case study A, post-hoc auditory feedback was used mainly for playing back student recorded performance-related data of the whole piece. This was followed by playing back recorded performance-related data of excerpts such as musical bar groups, in order to explore the silences between musical sections of the chosen piece, and the pedalling responses.

Unlike case study A, post-hoc auditory feedback in case study B involved listening back to selected musical excerpts of student performance-related data rather than the playing back of recorded data of the whole piece. Post-hoc auditory feedback was mainly used to compare musical excerpts for tempo relations according to the musical structure of the chosen piece.

As with case study B, post-hoc auditory feedback was used in case study C mainly to explore selected musical sections of the chosen piece. Unlike in case studies A and B, post-hoc auditory feedback in case study C also involved playing back teacher performance-related data. This was due to the frequent occurrence of teacher playing, and recording the correspondent performance-related data, in both lessons. Post-hoc auditory feedback at a slower tempo was used to play back student performance-related data in lesson 1, and separate teacher and student performance-related data in lesson 2.

Figure 8.2 illustrates microstructure analysis of two musical behaviour excerpts relating to additional auditory feedback in case study C. The first excerpt shows the post-hoc auditory feedback at the end of lesson 1 when working on musical bars 57-66. The second excerpt shows the post-hoc auditory feedback in the middle of lesson 2 when working on musical bars 110-112. Figure 8.2 also shows the pedagogical use of post-hoc auditory feedback at the original tempo, then at a slower tempo. The colour code illustrates post-hoc auditory feedback use per participant shown in red for the student, and yellow for the teacher generated performances. The colour shape code illustrates post-hoc auditory feedback in the original tempo as straight horizontal lines, and at a slower half tempo as wavy lines. Although post-hoc auditory feedback appeared to be used in case study C, the teacher did not seem to allow space for the student to play and practise immediately after listening back to their own recorded performance versions. Rather, the teacher played between the playing back moments of the student recorded performance-related data.

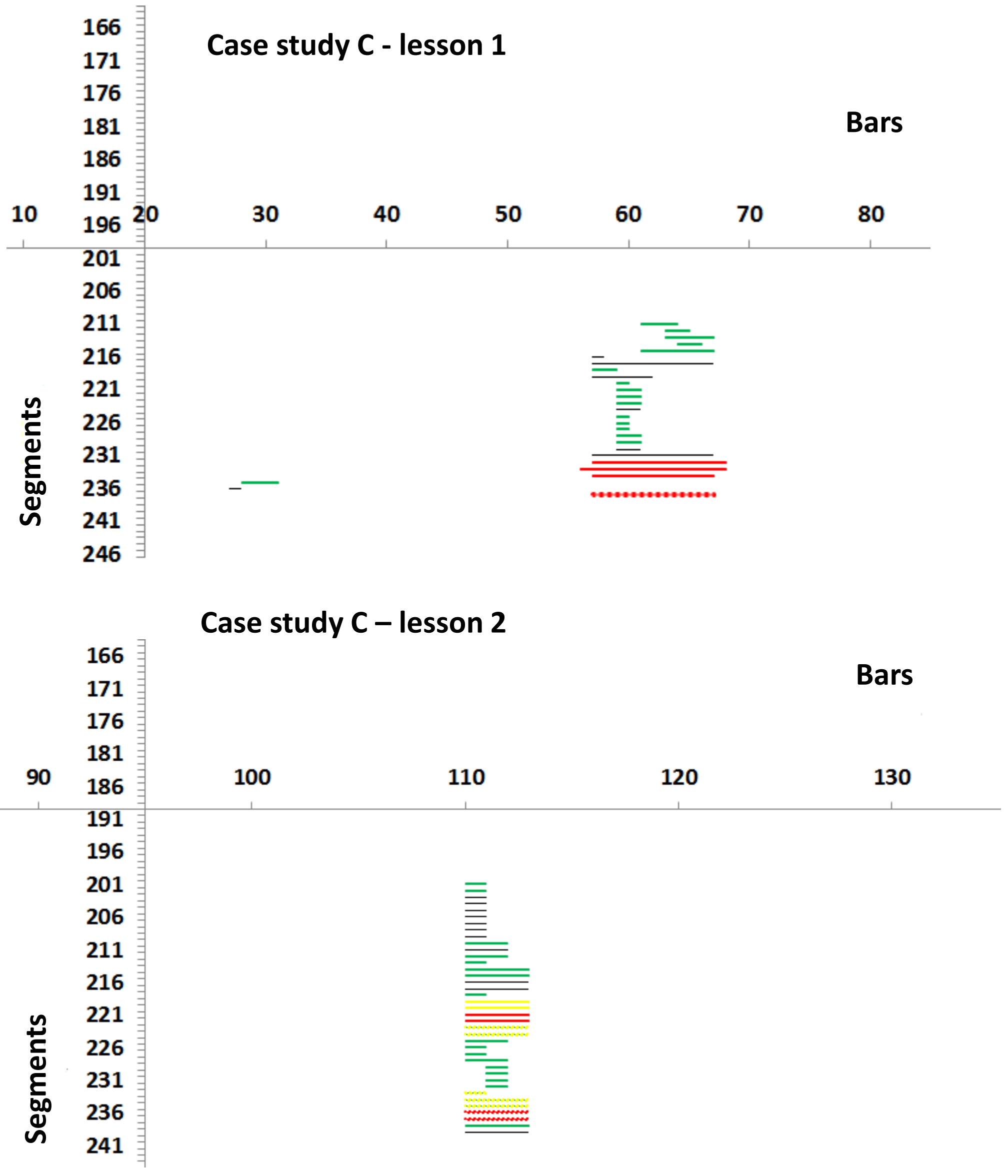


Figure 8.2 Microstructure analyses of two musical behaviour excerpts relating to post-hoc auditory feedback in case study C, lessons 1 and 2 (Mozart Piano Sonata No. 2 in F major, K. 280)

Colour code: red—post-hoc auditory feedback of student performance-related data at the original tempo (straight line) and at a slower tempo (wavy line); yellow—post-hoc auditory feedback of teacher performance-related data at the original tempo (straight line) and at a slower tempo (wavy line); black—real-time auditory feedback of student playing; green—real-time auditory feedback of teacher playing.

Key: X axes are not at the bottom of each graph because these two musical behaviours happened at around segments 200 in lesson 1 and 191 in lesson 2 at selected musical bar groups.

Generally, the application of post-hoc auditory feedback was used by teachers and students to listen back either to the entire recorded performance or to short musical excerpts of the recorded performance-related data in order for the student to be aware of their own performance outcome. When used for the purpose of checking, listening back to the performance-related data took place once, and when comparing, it took place twice. When listened back to twice, post-hoc auditory feedback was used either at the original or slower tempo. Case study C shows how listening back was used for the following pedagogical purposes. First, listening back enabled comparison of different versions of student recorded performance-related data before and after teacher verbal feedback. Second, listening back facilitated comparison of different versions of the recorded musical excerpt by different participants. Third, listening back to the recorded version by a participant twice enabled listening for different purposes, such as focusing on dynamics during the first listening and on tempo at the second listening.

Listening to previously recorded performance-related data might challenge those participants unused to it. Post-hoc auditory feedback which includes playing back a recorded performance appears an uncommon activity in piano lessons. Listening back to recorded data means listening to musical sections which were practiced repeatedly or those which showed memory lapses during the lesson. Considerations of such factors should be taken into account when applying post-hoc auditory feedback in a piano studio. While teacher and student may rarely have listened back to their own performances, this type of experience might cause anxiety in individual performers. Student participants in particular may be susceptible to this.

8.5 Real-time over post-hoc auditory feedback

The simultaneity of real-time and post-hoc auditory feedback occurred whenever there was a combination of playing by student, teacher, or both participants alongside my playing back of recorded performance-related data. This simultaneity could happen with or without a clear purpose. An attempt to use real-time over post-hoc auditory feedback with clear purpose happened in case study A, while an accidental occurrence happened in case study B.

The first example, relevant to the use of real-time over post-hoc auditory feedback with clear lesson focus, was noticed in case study A, lesson 2. Teacher A suggested a task whereby the student played and recorded the left hand part on the top of their own recorded right hand performance. Although this task was unsuccessful, perhaps due to my technical limitations, it nonetheless offers an additional use of real-time over post-hoc auditory feedback in piano lessons.

The second example, relating to the use of real-time over post-hoc auditory feedback without clear purpose, was an accidental occurrence. In case study B, lesson 2, the student played short musical excerpts while listening to their own previously recorded performances. This might indicate the urgency of the student to play as soon as any type of feedback is received, either from the teacher or additional auditory feedback.

8.6 Musical performance parameters and auditory feedback

The second aim of these microstructure analyses was to investigate musical performance parameters which were related to particular musical sections, such as specific musical bars, when technology-mediated feedback is applied in a piano studio setting. A performance cues matrix derived from inserting data on an SYMP spread sheet shows the intersection of selected bars with the particular musical performance parameters worked on per lesson and per case study. Through this performance cues matrix it was possible to determine the number of bars which were worked on for each musical performance parameter (see Table 8.1), and vice versa (see Appendix 11 for an example of a performance cues matrix) throughout the entire piano piece.

Table 8.1 shows a list of musical performance parameters which were worked on in each chosen piece and how many musical bars were related to them in each lesson per case study. For example, performance parameters such as motor control issues were worked on in 12 out of 74 bars in case study A, lesson 1, compared with 5 out of 162 in case study B, lesson 1, or with 29 out of 144 in case study C, lesson 1.

Table 8.1 The total number of musical bars worked on in lessons 1 and 2 across case studies in the three areas: music, performance and technology

Musical performance parameters		Auditory feedback					
		Case study A		Case study B		Case study C	
		Lesson 1	Lesson 2	Lesson 1	Lesson 2	Lesson 1	Lesson 2
Music	Harmony and tonality	3	9	0	0	5	13
	Music Structure	2	9	25	3	0	3
Performance	Articulation	4	1	16	48	7	11
	Dynamics	18	0	9	12	24	40
	Fingering	0	1	2	17	0	7
	Melodic accuracy	2	10	11	12	3	13
	Metaphors	0	0	0	0	23	0
	Motor control issues	12	0	5	23	29	11
	Other parameters	0	9	25	2	3	5
	Pedalling	0	0	4	13	15	0
	Phrasing	3	16	57	18	33	43
	Rhythmic accuracy	25	0	2	5	28	12
	Style	2	0	5	0	14	0
	Technique	2	9	33	18	25	17
	Tempo	0	7	52	27	36	12
	Touch	0	0	0	0	19	16
Technology	MIDI parameters	28	9	7	44	2	2

The performance cues matrix (see Appendix 11 for an example) demonstrates the occurrence of specific musical performance parameters in each musical bar of the chosen piece in each case study. These multiple layers of different musical performance parameters per musical bar suggest that the teacher has provided an accumulated feedback on student performance which lack clear focus.

Microstructure analyses also showed overlaps between technology and performance parameters for the same specific groups of musical bars of a chosen piece, per lesson, and case study. Technology, such as MIDI parameters and performance parameters, for example dynamics, overlapped in the same musical excerpts in case studies A and B. These overlaps reveal potential relationships between these parameters which were identified in the performance cues matrix. The high occurrence of these overlaps indicates that in case studies A and B, teacher and student pairs made associations between technology and performance parameters in their lessons. The low occurrence of technology parameters in case study C indicates that the teacher and student pair did not seem to have engaged with technology in their lessons at the same extent as case studies A and B.

However, when several parameters were involved per musical section, overlaps between technology and other musical performance parameters seemed to enhance learning. For instance, in case study A, lesson 1, technology overlapped with two musical performance parameters per specific musical excerpts, for example: articulation and dynamics; pedalling and rhythmic accuracy; and dynamics and rhythmic accuracy. In case study B, lesson 2, technology overlapped with one, two or three musical performance parameters per specific musical excerpts, such as: musical structure; pedalling; pedalling and fingering; and articulation, phrasing, and dynamics. In case study C technology overlapped with multiple musical performance parameters. This evidence suggests that the lesson focus is clearer when teacher and student pairs worked on a small number of musical performance parameters by relating them to technology in their lessons. It can be inferred that teacher and student pairs in case studies A and B might have engaged with technology in a deeper way than in case study C. However, in all case studies, when technology overlapped with a greater number of musical performance parameters per musical excerpt, feedback was accumulated on many parameters and the lesson focus was less clear.

The performance cues matrix analysis revealed there are too many musical performance parameters per musical excerpt within each case study. One implication is the tendency of participants to deliver feedback on various musical performance parameters for the same group of musical bars even when the lesson focus might only have been on one or two parameters. Multiple layers of musical performance parameters related to the same group of bars might not be useful for student learning. This might have led to accumulated feedback in some musical excerpts for particular musical performance parameters. It can be argued, then, that the fewer the number of parameters which were worked on by teacher and student pairs per musical excerpt, the clearer the lesson focus in order to improve student performance.

The observed overlaps between the parameters suggest a correspondence between technology and specific musical performance parameters when not many parameters are involved per musical excerpt. Once there is a clear correspondence between particular music or performance and technology parameters, in terms of MIDI parameters, it might be easier for the teacher and student to identify which musical performance parameters could actually be worked on in a piano lesson when technology-mediated feedback is used. Subsequently, finding out prospective relationships between technology and the other two parameters, namely music and performance, might be beneficial for future applications of technology in HE piano studio settings.

8.7 Summary

In this chapter, microstructure analyses of musical behaviours revealed the additional auditory feedback which was available in each lesson per case study. Musical behaviours are defined specifically as musical practice, which describes the moments of teacher or student playing, and listening back, which describes moments of playing back recorded performance-related data generated by teacher or student. SYMP software enabled microstructure analyses of these musical behaviours. The additional auditory feedback regarding the musical structure of the chosen piano piece in each case study was revealed through these analyses. Graphs were generated which plotted for each chosen piano piece the number of musical segments and their respective bars which were played or listened back to according to the musical bars of the chosen pieces.

Auditory feedback was available in piano lessons in real-time or post-hoc. Real-time auditory feedback was generated when the student, teacher or both participants were playing their chosen piece. Post-hoc auditory feedback occurred when I played back the recorded performance-related data generated by the student, teacher or teacher playing alongside the student. A combined form of real-time over post-hoc auditory feedback occurred when the student played alongside the recorded performance-related data. In addition, post-hoc auditory feedback was available at the original tempo and slower tempo as in case study C. The performance cues matrices plotted the multiple layers of musical performance parameters per musical bar in each chosen piano piece. The matrices indicate that teacher feedback was accumulated, as multiple musical performance parameters might not be related to a clear lesson focus. Overlaps of technology parameters, and music or performance parameters in the same musical bars, indicate relationships between them which can be used to clarify lesson focus in piano learning.

Overall, real-time auditory feedback was found to be related to the auditory feedback which is usually available in traditional one-to-one piano lessons. Post-hoc auditory feedback was found to be related to the additional form of auditory feedback which is available to teacher and student pairs only when technology-mediated feedback is present in a piano studio. The application of technology-mediated feedback enabled listening back to recorded performance-related data generated by participants. The pedagogical use of technology-mediated feedback in HE piano studios involved the application of additional auditory feedback. Specifically, post-hoc auditory feedback of student and teacher recorded performances were available for use. The application of post-hoc auditory feedback varied in three aspects: performer participants which generated the data, in terms of students and teachers; the length of the musical excerpts which were listened back to; and different recording versions of performance-related data. Post-hoc auditory feedback also varied in terms of the speed at which the recorded performance-related data was played back; participants could choose between the original tempo and a slower half tempo. In addition, the purposes for using post-hoc auditory feedback were context specific and varied according to the learning needs in each case study. Chapter 9 reports the findings of the MIDI QDA for additional visual feedback in HE piano studios.

9 MIDI QDA: findings in relation to additional visual feedback across case studies

9.1 Introduction

This chapter reports findings from the MIDI QDA for additional visual feedback which was available across all three case studies. MIDI data were generated by using DAW software for each piano lesson for a chosen repertoire. Excerpts of MIDI data are also analysed qualitatively across case studies. I recorded digital piano keyboard and pedalling activity using DAW software whilst the student, teacher or both participants were playing the chosen piano piece. The recorded performance-related data for the keyboard and pedalling activity could also be played back to the participants using DAW software. Real-time performance-related data were recorded using the DAW software and presented visually in piano roll form as a black and grey interface. When played back, the recorded performance-related data were presented in piano roll form as a coloured interface with gradations from green to red. This post-hoc visual feedback was used by participants when looking at the computer screen and/or listening back to the recorded performance. In summary, this chapter discusses the two additional forms of visual feedback which were available to participants across the three case studies either in real-time or post-hoc when technology-mediated feedback is applied in HE piano lessons.

9.2 Real-time visual feedback

RTVF was available to participants throughout each lesson while the student, teacher, or both were playing and I was recording the performance-related data correspondent to their performances through DAW software. RTVF was not available to participants if teachers asked for the recording of data to cease when students were playing. This request was made in case study C at specific points during lessons 1 and 2 because

RTVF seemed to be disturbing the teacher whilst providing feedback on student performance. RTVF, which was available in MIDI data through DAW software during playing, was simultaneously generated alongside auditory feedback. The application of RTVF by participants served two functions. First, this type of feedback was used by students to meet their individual learning needs, as demonstrated by case study A. Second, shared use occurred when the teacher worked alongside the student to assist their learning needs as in case study B. Overall, whereas in case studies A and B the participants assisted each other in understanding the MIDI notation as visual feedback, in case study C it was unclear how and to what extent the teacher and student were using the technology-mediated feedback as visual feedback. The use of RTVF seemed related to the improvement of student learning and performance regarding articulation and melodic accuracy as discussed below.

9.3 Real-time visual feedback for student individual learning needs

RTVF seemed to have been used only by the student in case study A in order to meet individual learning needs with regard to articulation when playing the Alberti bass for the left hand (see Figure 9.1). Student A seemed to have used RTVF as an individual experience whilst playing rather than using it with a clear lesson focus as a shared teacher-student experience. There was evidence of improvement in student learning and performance of articulation between lessons 1 and 2 in case study A.

Teacher A fed back that the student was holding their fingers too long on the keys when playing the Alberti bass. Student keyboard activity could be seen in the visualization on the DAW software interface which showed the MIDI notes corresponding to the musical notes. In lesson 1, left hand activity overlapped (see Figure 9.2) indicating that student A was holding the keys too long as perceived by the teacher. In lesson 2 most of the MIDI notes did not overlap, but were in a more consecutive mode (see Figure 9.3) indicating that the student was playing legato as requested by the teacher.

This improvement in performance between lessons 1 and 2 suggests that student A was more aware of holding keys too long when playing. Left hand legato for Alberti bass was enhanced by seeing overlapping or consecutive MIDI notes which supports the use of RTVF as a means of enhancing student learning.

Figure 9.1 Mozart Piano Sonata No. 16 in C major, K. 545, fragment, second movement, bars 1-8 (Leipzig: Peters, 1938)

Key: Taken from IMSLP website (http://imslp.org/)

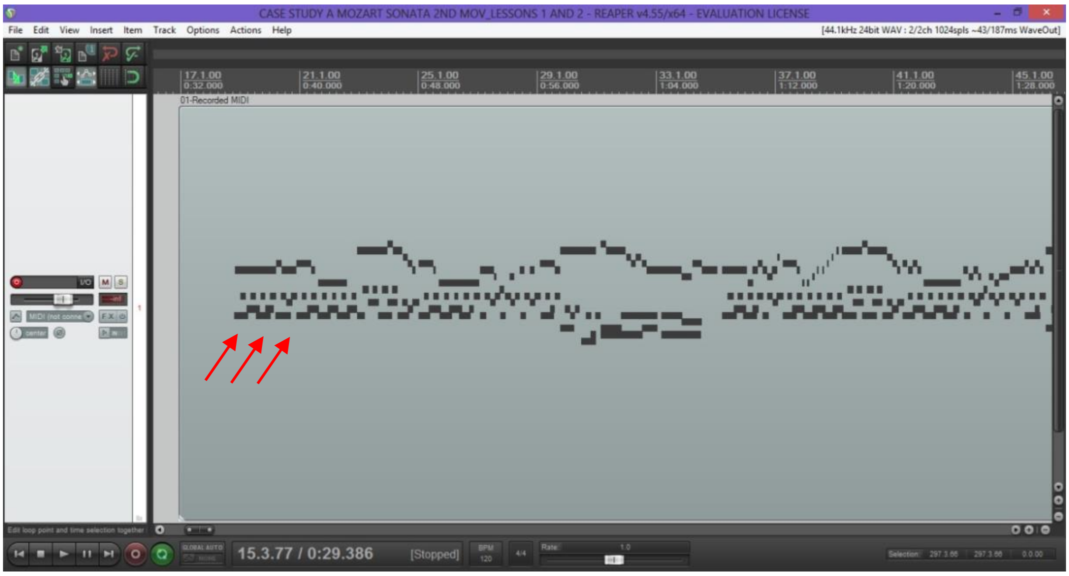


Figure 9.2 DAW software screenshot focusing on articulation in case study A, lesson 1

Key: The arrows show MIDI notes corresponding to the left hand activity of student playing in holding notes too long in case study A, lesson 1.

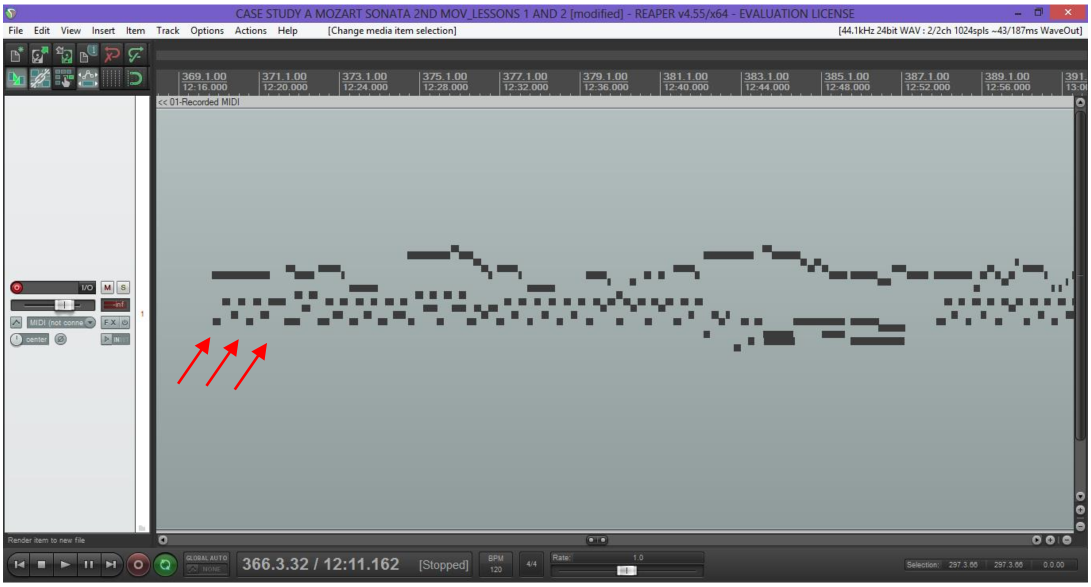


Figure 9.3 DAW software screenshot focusing on articulation in case study A, lesson 2

Key: The arrows show MIDI notes corresponding to the left hand activity of student playing in a more consecutive mode indicating legato articulation in case study A, lesson 2.

Student A seemed to have made sense of holding keys too long when playing Alberti bass and used RTVF to improve left hand articulation. This improvement was independent of any awareness or guidance from the teacher. The application of RTVF in case study A seemed related to personal interaction with the technology in order to meet individual needs. Neither participant in case study A seemed to have perceived or made sense of the RTVF in a synchronized way. This lack of synchronicity suggests that RTVF might be closely related to the way individuals engage with the additional feedback, and use it to enhance their intrapersonal feedback.

9.4 Real-time visual feedback: teacher working alongside student

In case study B, RTVF was used as a shared experience between the teacher and student. The teacher seemed to have used additional RTVF alongside the student to make the student aware of their own performance on a specific aspect that the teacher had already noticed through auditory or visual feedback. RTVF was applied in case study B in order to improve student performance for articulation, such as finger legato for top notes between chords, holding fingers when playing arpeggios, and chord attack and release, and melodic accuracy, for example, the missing bass chord note of the left hand.

The first application of RTVF happened as the pair worked on the articulation of finger legato between chords in the right hand, which was perceived by teacher B in lesson 1 (see Figure 9.4). Initially, teacher B perceived and then gave feedback on student performance for articulation since the top notes of two chords were not being connected when the student played. Then the teacher realised that the additional visual feedback in real-time was showing that information on the computer screen which could support student learning. The chords written for the right hand were supposed to be played with a legato articulation between the fingers according to both the printed notation and teacher feedback. However, RTVF correspondent to this finger activity on the keyboard showed that the chords were not being connected. The main reason why this might have happened is that the top note finger of the right hand was not being held down until the fingering change occurred. Figure 9.5 shows the screen shot of the DAW software according to the chords on the musical score (Figure 9.4) where there was no connection between fingers, such as finger legato, for the top notes of the chords.

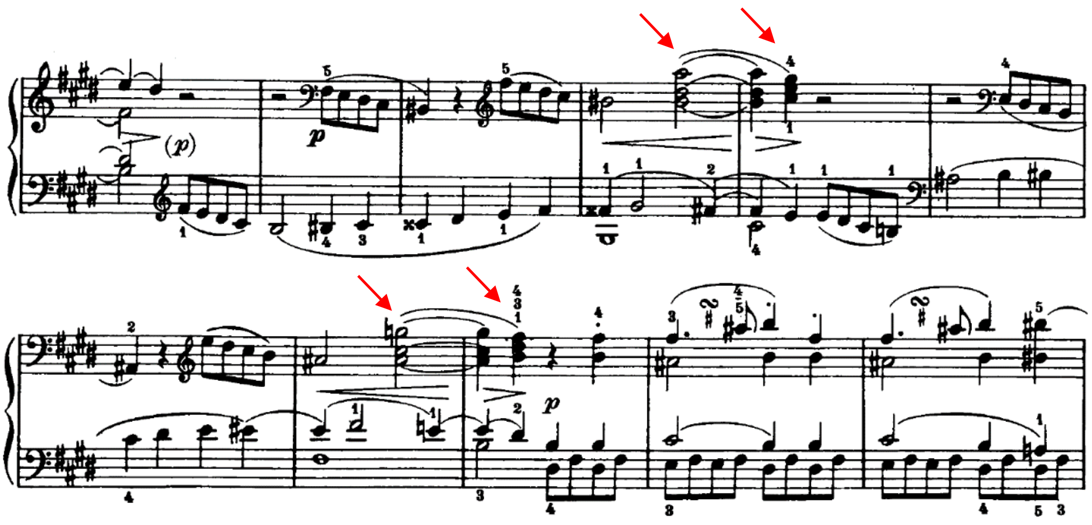


Figure 9.4 Beethoven Piano Sonata No. 9 in E major, Op. 14, No. 1, fragment, first movement, bars 30-40 (Leipzig: Peters, 1920)

Key: Taken from IMSLP website (http://imslp.org/). The arrows in bars 33-34 and 37-38 indicate the top notes of the chords which were requested to play legato articulation.

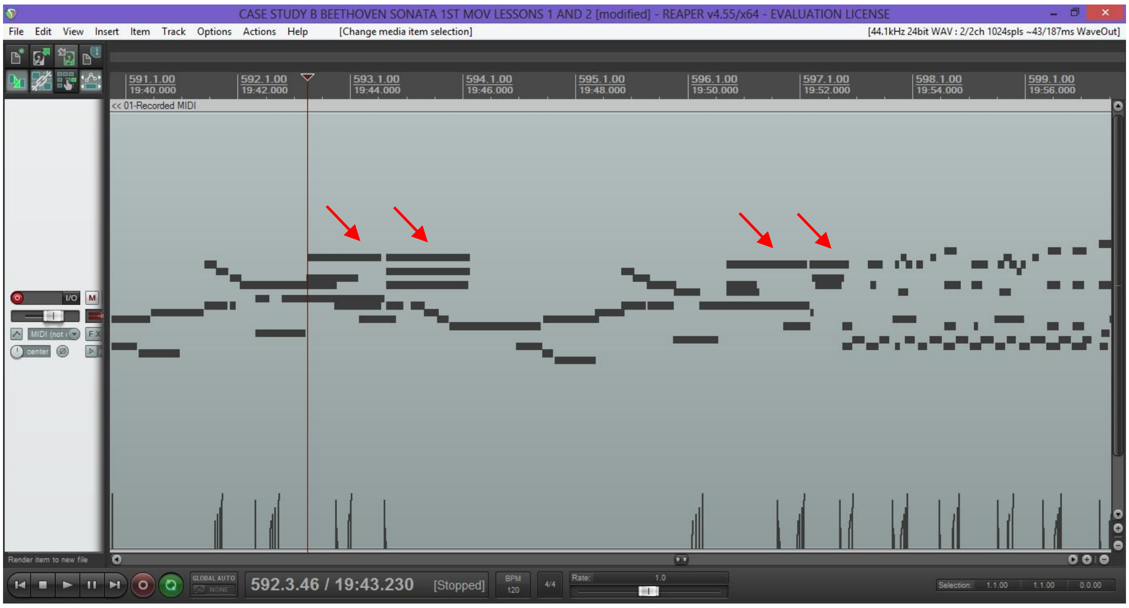


Figure 9.5 DAW software screenshot focusing on articulation in case study B, lesson 1

Key: Finger legato between chords was identified by overlaps between top MIDI notes.

There was evidence of the application of RTVF in case study B, lesson 1 for articulation, specifically finger legato between chords, even though a combination of factors was required to improve student learning and performance. It was unclear whether enhancement of student performance for articulation was observed due to the use of RTVF, repeated trial and error by the student, or teacher modelling of the finger legato alongside student playing.

The second application of RTVF in case study B happened in lesson 2 when the pair worked on articulation of notes and fingers on left-hand note arpeggios. By this second lesson, the teacher had also realised the benefit of using additional RTVF to show that the student was holding the second note, such as finger 3, when playing arpeggios in bar 65 (Figure 9.6). After realising this (see Figure 9.7), the teacher suggested a fingering change from finger 3 to finger 4 which resolved the issue. The positive outcome of this was the improvement of student performance for articulation of the arpeggio notes in the left hand once a more appropriate fingering was used.

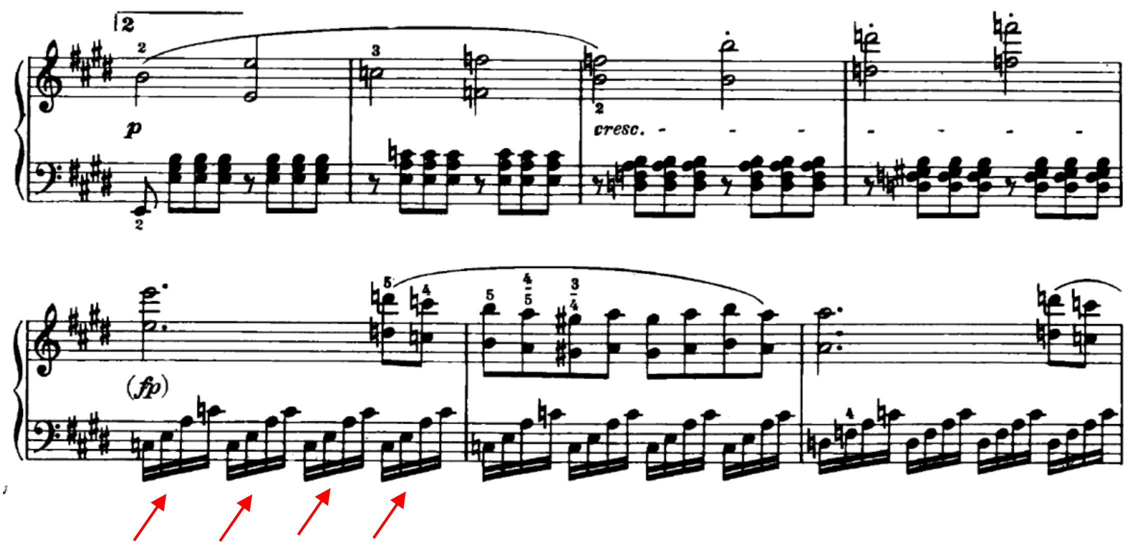


Figure 9.6 Beethoven Piano Sonata No. 9 in E major, Op. 14, No. 1, fragment, first movement, bars 61-67 (Leipzig: Peters, 1920)

Key: Taken from IMSLP website (http://imslp.org/). The arrows in bar 65 indicate the second note of the arpeggio in the left hand which were being held too long when using finger 3

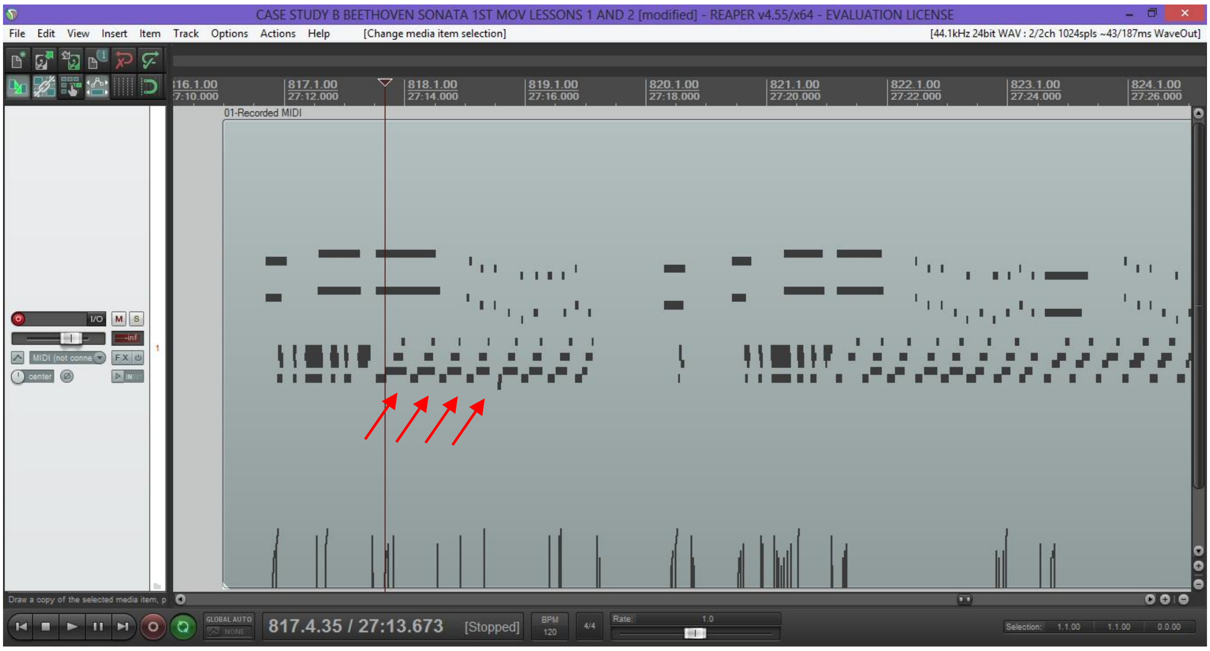


Figure 9.7 DAW software screenshot focusing on articulation in case study B lesson 2

Key: The arrows show MIDI notes corresponding to notes of the arpeggios in the left hand which were held too long in case study B, lesson 2, when using finger 3

The third application of RTVF in case study B happened when the pair worked on articulation of chord attack and release in lesson 2. The teacher used RTVF to make the student aware of note asynchrony for chord attack and release in bars 112 to 113. Figure 9.8 shows the chords as an excerpt of the music score. Figure 9.9 shows the correspondent visualization on the DAW software interface with several trials of the chord sequence. RTVF was used mostly by the teacher to identify the chord asynchrony and alert the student about this issue. However, the extent to which student performance for articulation of chord attack and release improved during lesson 2 is unclear.

Figure 9.8 Beethoven Piano Sonata No. 9 in E major, Op. 14, No. 1, fragment, first movement, bars 110-114 (Leipzig: Peters, 1920)

Key: Taken from IMSLP website (http://imslp.org/). The arrows in bars 111 and 112 indicate the articulation of chord attack and release which was expected to be even between fingers

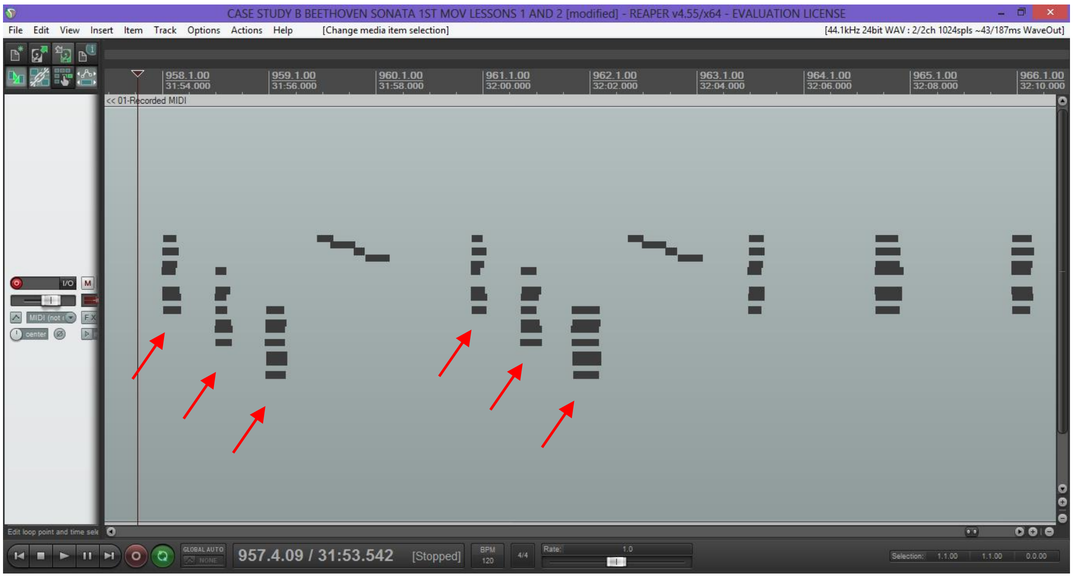


Figure 9.9 DAW software screenshot focusing on articulation in case study B, lesson 2

Key: The arrows show MIDI notes corresponding to chord notes attack and release which were identified to be in asynchrony, in case study B, lesson 2.

The fourth and last application of RTVF in case study B, lesson 2, happened when the pair worked on melodic accuracy. The bass notes of the left hand chords at the opening of the theme were found to be missing. The teacher perceived the bass notes (see Figure 9.10) were missing when looking at the correspondent visualization on the computer screen in real-time (see Figure 9.11). It is unclear whether teacher B observed the missing bass notes primarily through auditory feedback, and then as RTVF, vice versa, or simultaneously.

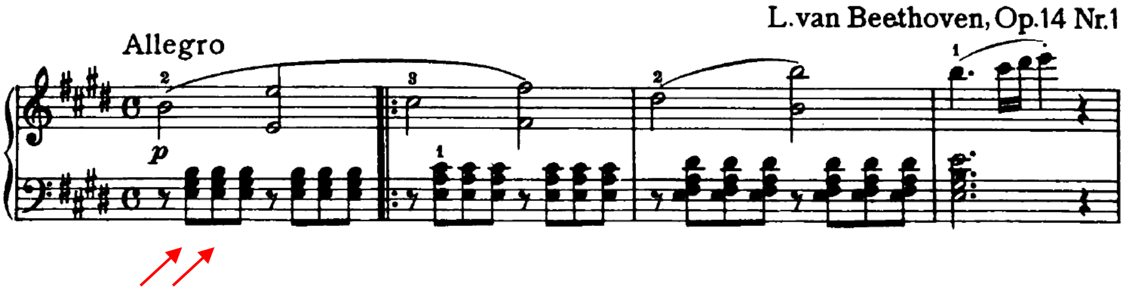


Figure 9.10 Beethoven Piano Sonata No. 9 in E major, Op. 14, No. 1, fragment, first movement, bars 1-4 (Leipzig: Peters, 1920)

Key: Taken from IMSLP website (http://imslp.org/). The arrows in bar 1 indicate the bass notes of the left hand chords which were found to be missing in case study B lesson 2.

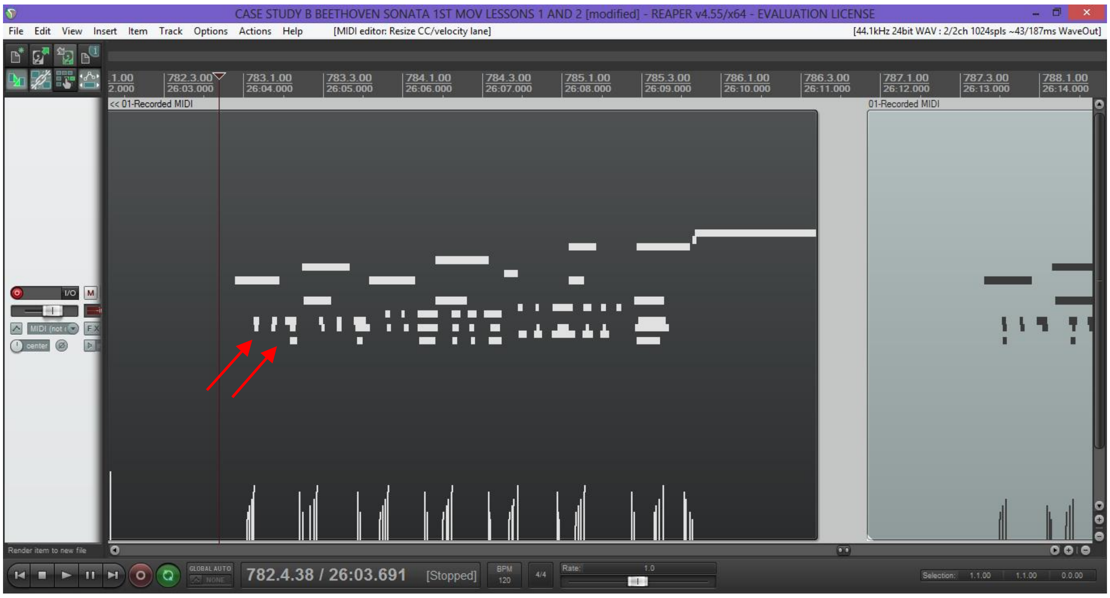


Figure 9.11 DAW software screenshot focusing on melodic accuracy in case study, B lesson 2

Key: The arrows show MIDI notes corresponding to the bass notes of the left hand chords which were found to be missing in case study B lesson 2.

The application of RTVF appeared closely related to the particular way it was perceived by individuals, and this might be related to their individual differences and intrapersonal feedback. In case study B, the teacher seemed to have understood the applicability of RTVF in a much clearer way than student B. Teacher B was consequently able to support student B in making sense of the feedback. Teacher B used additional visual feedback in identifying the performance goals to be worked on in lessons, and in supporting student learning through its use. In this example, the effective application of RTVF as a shared experience in an HE piano studio depends on a rapid and simultaneous understanding of its application by both teacher and student.

9.5 Post-hoc visual feedback

Post-hoc visual feedback use occurred when previously recorded performance-related data was made available to participants. This performance-related data, which was recorded using DAW software, was available to participants in combination with or without auditory feedback. Post-hoc visual feedback in normal mode was used alongside auditory feedback when I played back the recorded data. Post-hoc visual feedback in silent mode was applied when I switched the computer screen, and scrolled the visualization up and down, and from right to left, for example. The application of post-hoc visual feedback in combination with auditory feedback was identified with shared teacher and student use across all three case studies. The use of silent post-hoc visual feedback was observed solely in case study A where only the visualization of performance-related data was available to participants. When post-hoc visual feedback was used without a clear focus in lessons, it is possible that visual feedback was functioning to enhance auditory feedback, thereby creating a more attentive listening experience of the musical performance. The use of post-hoc visual feedback seemed to be related to the improvement of student learning and performance regarding articulation, rhythmic accuracy, dynamics, and pedalling, as discussed below.

9.6 Post-hoc visual feedback: teacher working alongside student

Post-hoc visual feedback in normal mode seemed to have been applied in order to work on student performance relating to articulation of the left hand in Alberti bass, and rhythmic accuracy between musical sections. The first application of post-hoc visual feedback in case study A seemed to impact not only on student performance but also on teacher support of the student. The improvement in student performance for articulation of the left hand in Alberti bass in bars 1-4 (Figure 9.1) can be seen between lesson 1 (Figure 9.12) and lesson 2 (Figure 9.13). It is suggested that the visualization in the DAW software interface for post-hoc visual feedback might be clearer and in more detail than for RTVF. Figure 9.12 shows the piano roll visualization of the performance data where the bottom MIDI notes correspond to the keyboard activity for the left hand notes of the Alberti bass. When comparing both lessons there is evidence of improvement in student performance in lesson 2 where the MIDI notes did not overlap as much (Figure 9.13). However, it was noticed that improved left hand articulation coincided with reduced melodic accuracy and increased memory lapses.

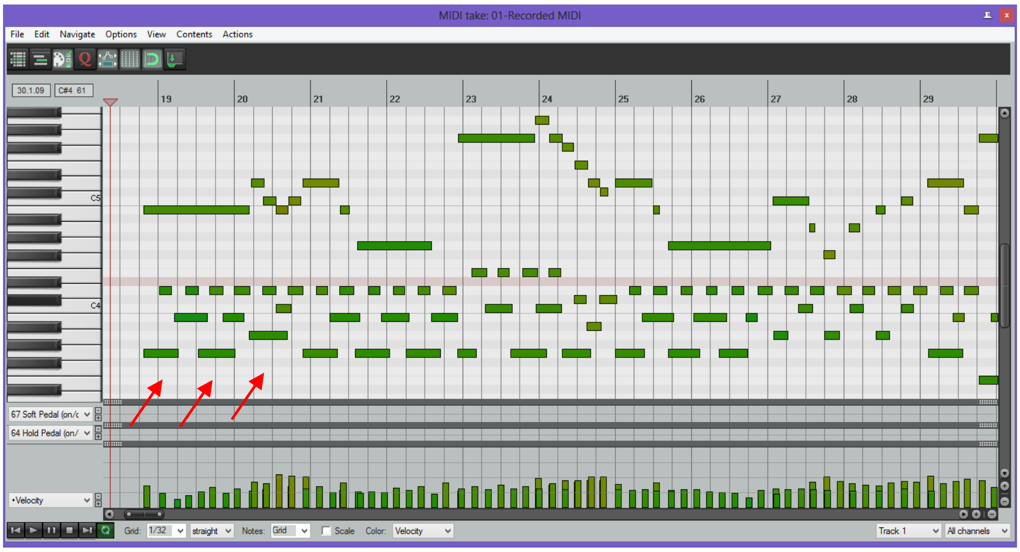


Figure 9.12 DAW software screenshot focusing on articulation in case study A, lesson 1

Key: The arrows show overlapped MIDI notes corresponding to notes held too long in the left hand of student playing in case study A, lesson 1.

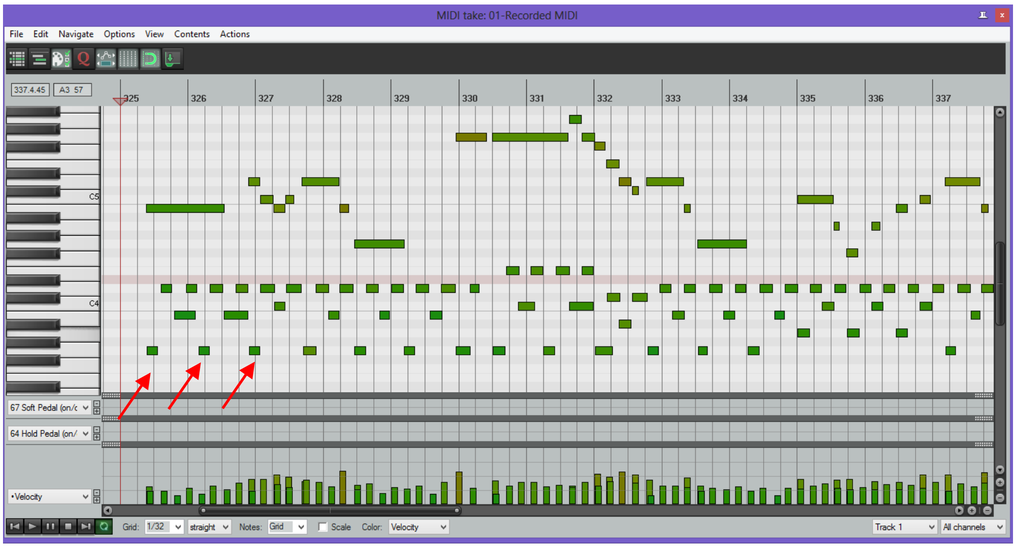


Figure 9.13 DAW software screenshot focusing on articulation in case study A lesson 2

Key: The arrows show consecutive mode of MIDI notes corresponding to legato articulation in the left hand of student playing in case study A, lesson 2.

The second application of post-hoc visual feedback in case study A related to, and was used for, improving rhythmic accuracy of rests between musical sections of the chosen piece. The teacher perceived rhythmic inaccuracy because the student was not resting long enough between musical sections. After using the post-hoc visual feedback, the student realized the extent to which the rests were rhythmically imprecise. The student performance seemed to have improved in this respect from lessons 1 to 2 in this musical excerpt (Figure 9.14). The correspondent visualizations of this musical excerpt are shown in Figure 9.15 in the DAW software interface. When compared to each other, the two visualizations show different sized spaces between MIDI notes, which correspond to the rests which were shortened in lesson 1. In lesson 2, improvement was noticed in student performance and there was evidence of learning for rhythmic accuracy since the spaces between MIDI notes were greater than in lesson 1.

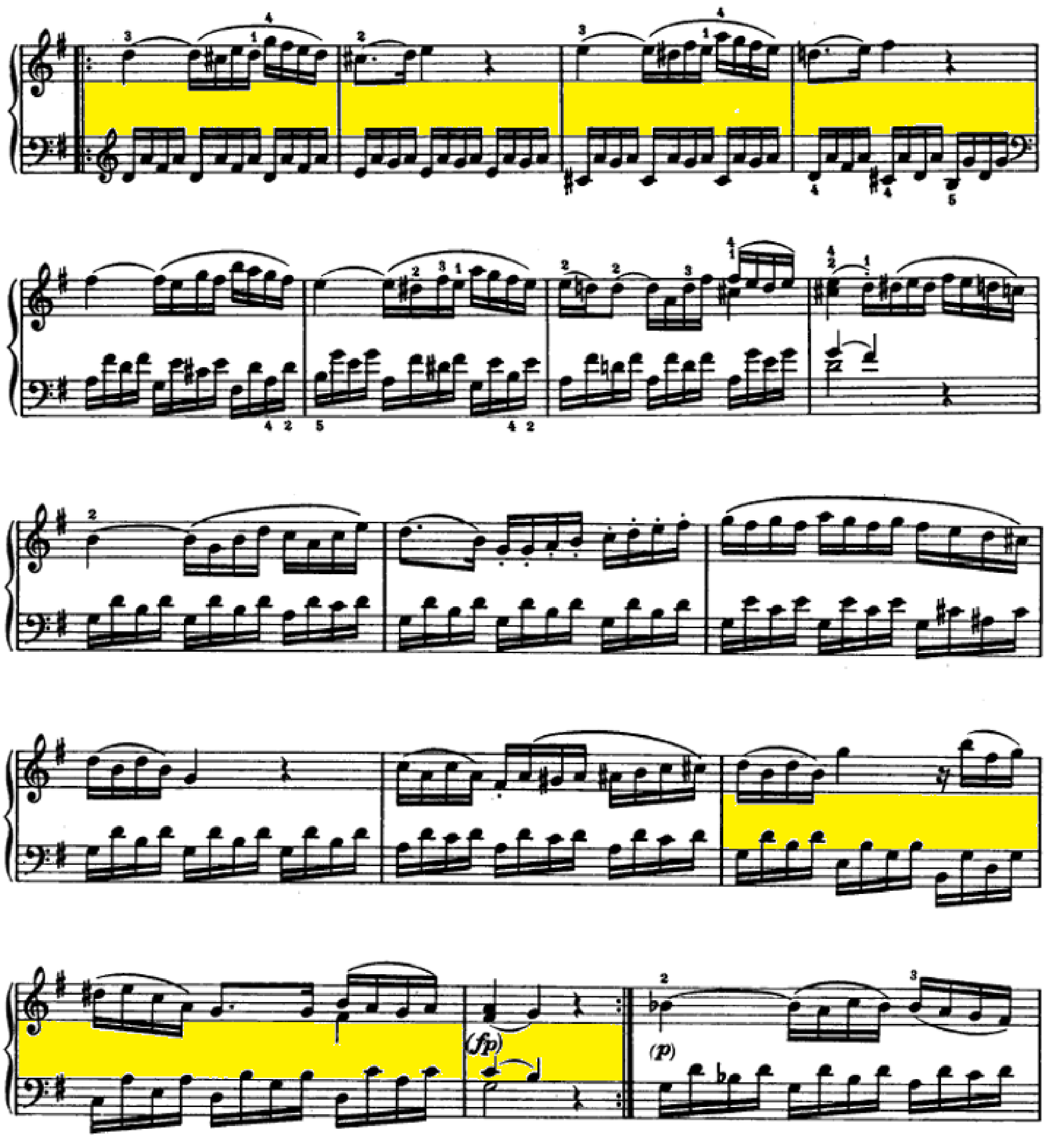


Figure 9.14 Mozart Piano Sonata No. 16 in C major, K. 545, fragment, second movement, bars 17-33 (Leipzig: Peters, 1938)

Key 1: Taken from IMSLP website (http://imslp.org/).

Key 2: The yellow highlighting shows the musical excerpt which was worked on in case study A, lesson 1, from bars 30-32 with ritornello to bars 17-20. The rest in bar 32 was perceived to be short by teacher A.

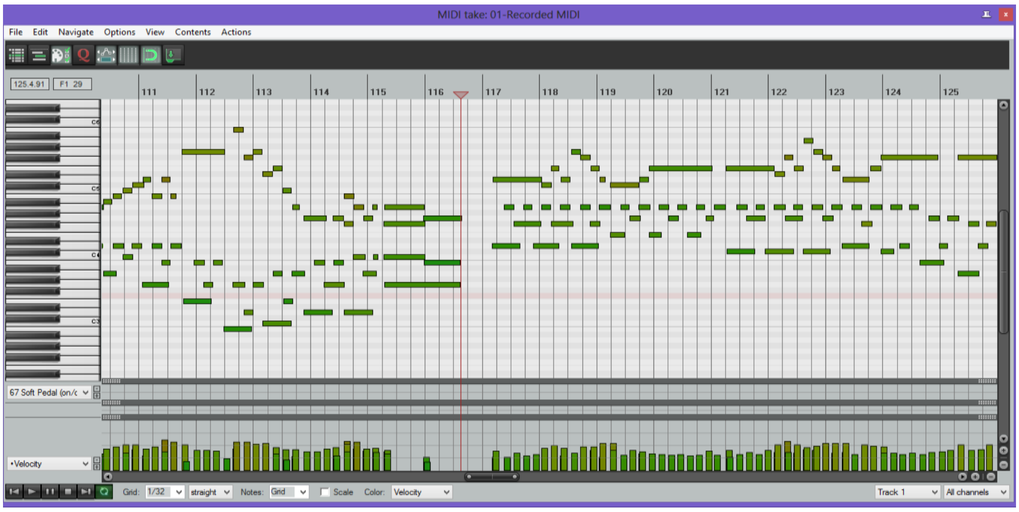


Figure 9.15 DAW software screenshot focusing on rhythmic accuracy in case study A, lesson 1

Key: The vertical red line denotes the beginning of the MIDI sized space correspondent to the rest in bar 32 which was perceived to be short in case study A lesson 1. Shading differences of the MIDI notes denote differences in dynamics across notes.

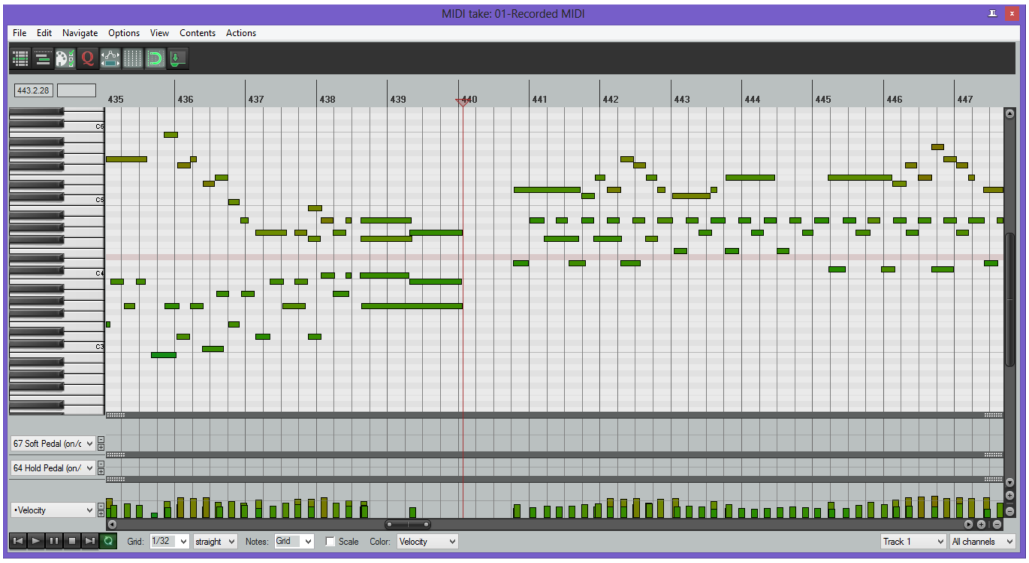


Figure 9.16 DAW software screenshot focusing on rhythmic accuracy in case study A, lesson 2

Key: The vertical red line denotes the beginning of the MIDI sized space correspondent to the rest in bar 32 which was greater indicating improvement in student performance in case study A, lesson 2. Shading differences of the MIDI notes denote differences in dynamics across notes.

In general, the teacher and student pair seemed to be applying post-hoc visual feedback in combination with auditory feedback. There was also evidence of how the application of post-hoc visual feedback enhanced student learning regarding articulation and rhythmic accuracy. Examples include improvement to left hand legato for Alberti bass through being able to see overlapping or consecutive MIDI notes, and silences between music sections which were revealed as spaces between MIDI notes, respectively. Teacher and student participants identified MIDI parameters and made associations with musical performance parameters in order to achieve a clear performance goal in the piano lessons.

9.7 Post-hoc visual feedback in silent mode: teacher working alongside student

Post-hoc visual feedback in silent mode occurred when the computer screen was scrolled from left to right, top to bottom, or vice-versa, and when the frozen computer screen was used with a clear purpose in silent mode. The application of silent post-hoc visual feedback occurred in case study A with a clear purpose mainly when the teacher and student were working on dynamic balance, between right and left hands. In lesson 2, the teacher wanted to make the student aware of the balance that could be achieved between the right and left hands for the opening musical bars (Figure 9.17) so that the left hand could accompany the dynamics contour provided by the right hand.

Two recordings of performance-related data correspondent to the piano performances were made. In the first recording, the student played alone with both hands. In the second recording, the teacher played the right hand alongside the student who played the left hand. The resulting recorded performance-related data were assessed initially by post-hoc visual feedback with auditory feedback, and then by silent post-hoc feedback. Visual feedback of both recordings of performance-related data, the student alone and teacher alongside the student, showed two main differences in silent post-hoc visual feedback, shown in terms of different colours (Figure 9.18) and different key velocity numbers (Figure 9.20). Greater colour differences were observed when the student accompanied the right hand of the excerpt played by the teacher (Figure 9.19) when compared to the colour differences when the student played alone (Figure 9.18). Similarly, Figure 9.20 shows greater differences in key velocity numbers when the student accompanied the right hand of the excerpt played by the teacher. In both instances, the differences mean that the dynamics contour was greater when the teacher played alongside the student.

Figure 9.17 Mozart Piano Sonata No. 16 in C major, K. 545, fragment, second movement, bars 1-12 (Leipzig: Peters, 1938)

Key: Taken from IMSLP website (http://imslp.org/).

Differences between the two visualizations of recorded performances were also noticed once the key velocity numbers visualization option was turned on. Figure 9.20 was generated in order to show how student left hand performance for dynamics contour changed. The key velocity number per each played note in sequential order was plotted when the student played both hands alone and when accompanying the right hand performance of the teacher.

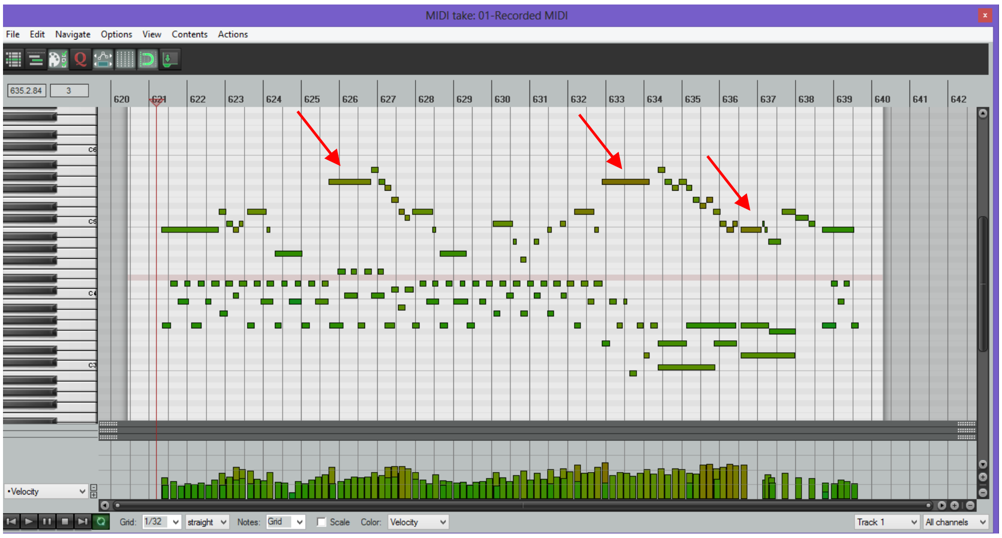


Figure 9.18 DAW software screenshot focusing on dynamic contour in case study A, lesson 2 when the student is playing alone

Key: Shading differences of the MIDI notes denote differences in dynamics across notes. The arrows indicate the slight dynamic contour on the right hand performance of the student.

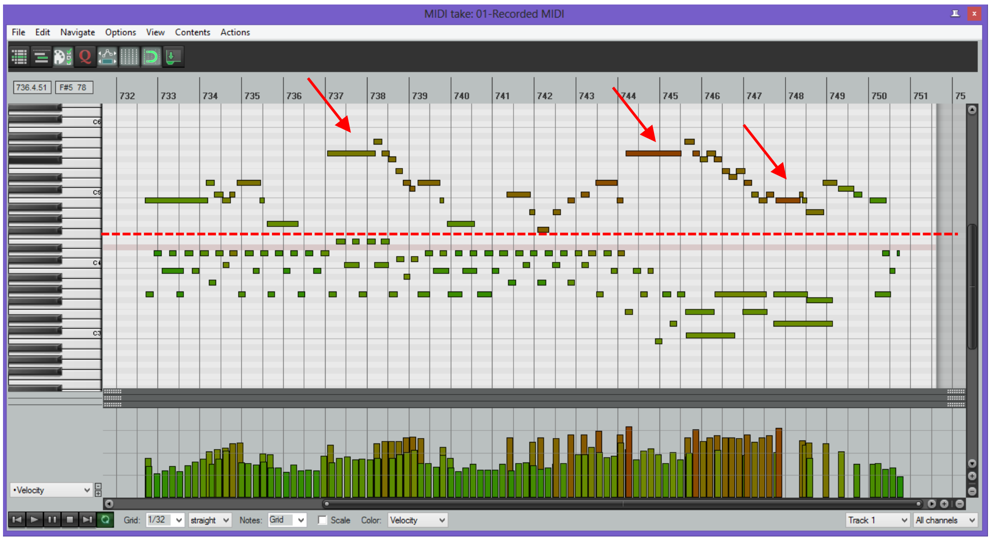


Figure 9.19 DAW software screenshot focusing on dynamic contour in case study A, lesson 2 when the teacher plays alongside the student

Key: Shading differences of the MIDI notes denote differences in dynamics across notes. The horizontal red dashed line indicates upper right hand notes by teacher playing and bottom left hand notes by student playing. The arrows indicate the great dynamic contour on the right hand performance of the teacher.

Figure 9.20 shows the key velocity number versus the sequential number of the left hand MIDI notes for bars 1 to 8. The higher key velocity numbers occurred when the student was accompanying the teacher who played with exaggerated intention. The graph indicates that the student was responding to the dynamic contour proposed by the teacher. The change in key velocity numbers indicated a change in the dynamic contour for the student left hand when playing alongside the teacher right hand. This response of the student to the teacher's playing was evident only in case study A.

In this sense, there is evidence that through the application of silent post-hoc visual feedback, represented both in colour and key velocity number, the student changed the way they were playing. The dynamic contour of the left hand was shown to have increased when accompanying the right-hand performance of the teacher. This outcome, which occurred when silent post-hoc visual feedback was used, suggests improvement in student learning and performance for dynamics with regard to contour or balance.

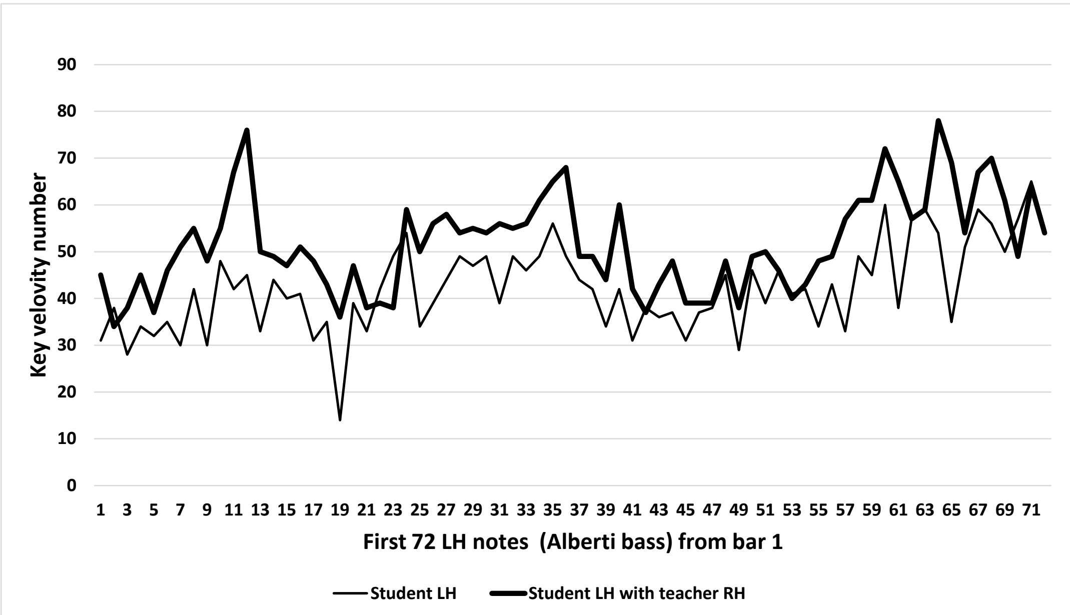


Figure 9.20 Differences in dynamic contour through key velocity numbers when the student played alone (bottom line), and accompanied by the teacher playing the right hand (top line)

The participants in case study A seemed to have had a quick response to the silent post-hoc visual feedback even before listening back to the recorded performance. Perhaps in case study A the visual feedback itself without auditory feedback was sufficient to inform the teacher and student what had happened in the performance. There was evidence that silent post-hoc visual feedback enhanced student learning regarding dynamics. Examples include improved student performance when the balance between the right and left hands was shown as variations to MIDI notes colour or MIDI notes key velocity numbers.

Post-hoc visual feedback use with clear lesson focus, in normal or silent mode, was observed in one case study rather than in all of the three. Visual feedback generated from recordings of performance-related data in the DAW software was available in all lessons, and could have been used at any time by teacher and student in any of the case studies. However, individual differences within and across the case studies indicate the different applications of technology-mediated feedback for visual feedback. This range of applications demonstrates that even when there was no evidence of the application of additional visual feedback, there is potential for its use either in real-time or post-hoc in HE piano learning.

9.8 Post-hoc visual feedback: attentive listening function

Post-hoc visual feedback in normal mode was available to participants as simultaneous auditory and visual feedback when the teacher and student pairs seemed to be looking at the computer screen while the performance-related data were played back. Although post-hoc feedback was the most observed type of technology-mediated feedback use across case studies, the extent to which it was used as visual feedback is discussed. Post-hoc visual feedback seemed to be used more for auditory feedback than visual feedback when teacher and student pairs did not make associations between technology and other musical performance parameters. Thus, it can be argued that the use of post-hoc visual feedback by teacher and student pairs functioned as attentive listening to musical performances in their lessons.

Attentive listening is related to listening back to a performance with simultaneous visual representation on the computer screen. Post-hoc visual feedback was clearly explored in case studies A and B rather than in case study C. For example, it was used with a clear lesson focus when teacher and student pairs made associations between technology and other musical performance parameters. However, the use of post-hoc visual feedback as attentive listening occurred when teacher and student pairs focused on music and performance parameters commonly found in conventional piano lessons.

Overall, post-hoc visual feedback might have supported and augmented the auditory feedback of participants through promoting attentive listening in all three case studies. Attentive listening contributed to student learning in particular as they were not playing while listening back to their previously recorded performance-related data. The application of post-hoc visual feedback might have enhanced the listening experience of teachers and students since visual feedback was seen to have supported pairs in developing a more attentive listening style which subsequently enhanced their auditory feedback in lessons.

9.9 A potential use of additional feedback in piano learning

Additional feedback was available for all three teacher and student pairs to be used at any time in the lessons. The application of additional visual-auditory feedback, observed across case studies, differed in how the teacher and student pairs interacted with the technology whether in visual or auditory mode and in real-time or post-hoc (see previous sections).

On occasions, additional visual-auditory feedback was identified by teacher and student pairs. However, it did not seem to be applied in the lessons with a clear lesson focus to improve student learning and performance. This apparent inability to apply the technology demonstrates a potential use of the additional visual-auditory feedback in HE piano learning in order to support or extend traditional pedagogical approaches.

One potential use of post-hoc visual feedback for pedalling occurred in case study A lesson 1. Here, the teacher and student pair explored visual responses on the computer screen according to different pedal-use styles when the student played a musical excerpt. Figure 9.21 show the post-hoc visual feedback on the DAW software interface for three different uses of the right foot pedal for the same excerpt. The first pedalling use was random. The second use occurred at the end of the musical excerpt. The third use happened throughout the excerpt. Pedalling activity on the DAW software interface was shown below the keyboard activity from the musical excerpt played by the student. The pedal activity for the sustain or right foot pedal was given by the hold pedal while that for the damper or una corda pedal was given by the soft pedal on the DAW software interface.

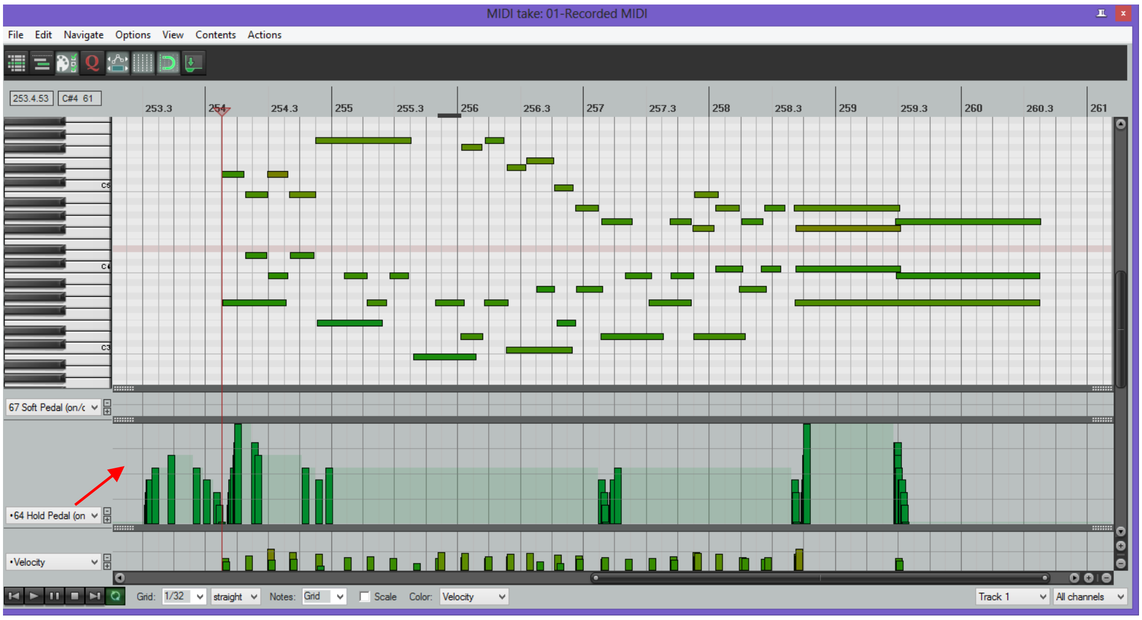


Figure 9.21 DAW software screenshot focusing on pedalling responses in case study A (first use)

Key: Hold pedal states for right foot pedal. The vertical red line denotes the beginning of the pedalling use when playing a musical excerpt. The arrow indicates the right foot pedal use.

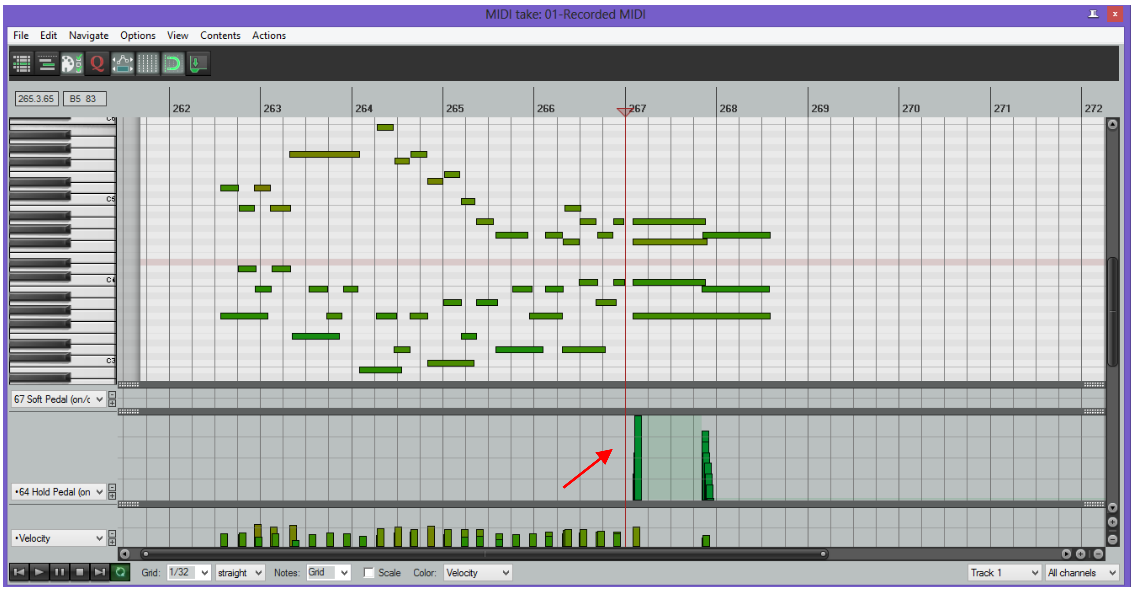


Figure 9.22 DAW software screenshot focusing on pedalling responses in case study A (second use)

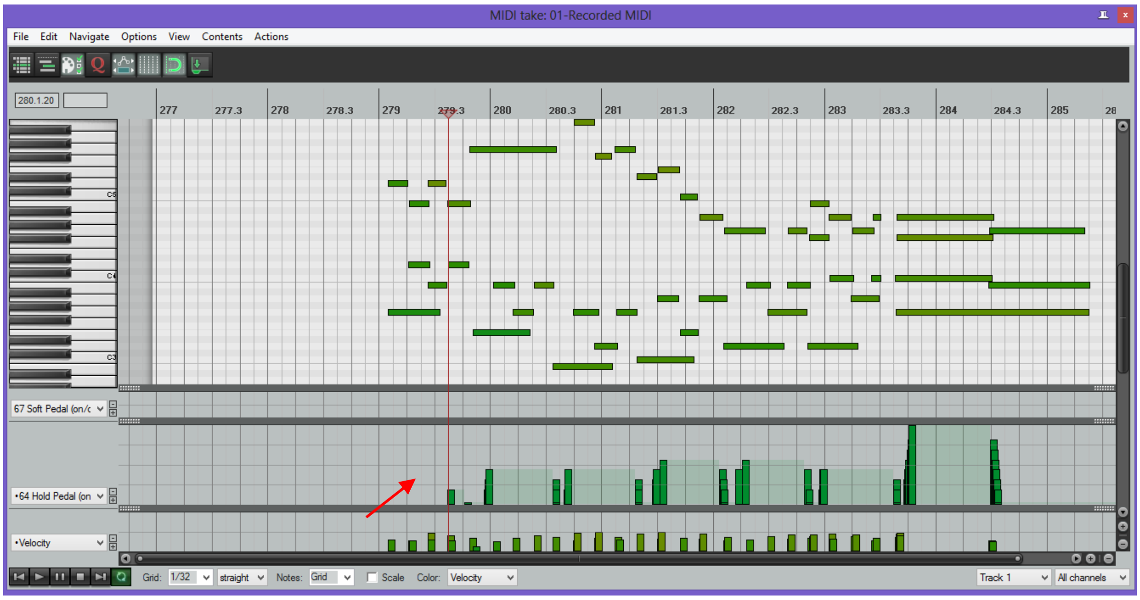


Figure 9.23 DAW software screenshot focusing on pedalling responses in case study A (third use)

For this task, teacher A asked the student to change the frequency of pedal use and also to press the right foot pedal at different levels for each of the three attempts. Although student A used the right foot pedal in the chosen piece for the first time in lesson 1, the student immediately perceived the visual response to the pedalling and also assisted the teacher to identify pedalling responses. Although the teacher and student pair identified pedalling responses through additional visual-auditory feedback, they did not seem to have applied the feedback for a clear lesson focus in terms of enhancing student learning and performance. Participants explored and identified pedalling responses for various conditions of pedal use, such as different levels of pedal and change frequencies; this generated different types of visual feedback for pedal action. The example by student A illustrates a potential use of additional visual-auditory feedback, particularly for the improvement of pedalling in student learning and performance. It suggests that additional feedback could help to support and extend traditional one-to-one piano tuition by bringing a multi-dimensional pedagogical approach to HE piano studios.

For teachers and students in HE piano studios, the application of technology-mediated feedback seemed to make the lesson foci clearer and performance goals well-defined for particular musical performance parameters. In case study A, the lesson focus was clearer in respect of articulation when a student used RTVF for their individual needs in order to enhance student learning and performance. Through shared teacher and student experience in case study B, the enhancement of student learning was achieved when the teacher used RTVF alongside the student to render performance goals clearer with regard to articulation and melodic accuracy. The performance goals seemed to be well-defined when using post-hoc visual feedback in combination with auditory or silent mode feedback, to improve student performance in articulation, rhythmic accuracy, and dynamic contrast when the teacher used it alongside the student. Post-hoc visual feedback seemed to augment the auditory feedback of teacher and student pairs through promoting attentive listening when they were not playing. Additional feedback also showed a potential use to enhance student performance in pedalling. This evidence-based discussion has indicated that student learning and performance improved when technology-mediated feedback was used and made the lesson foci clearer and well-defined in respect of articulation, melodic accuracy, rhythmic accuracy, and dynamic contrast in this study.

9.10 Summary

The application of additional visual feedback in HE piano studios was evidenced through MIDI QDA for the particular moments when there was a clear focus on the improvement of student learning and performance. RTVF was used by participants in individual and shared experiences. First, RTVF was used solely by students working on their own in order to meet their particular individual learning needs. Second, RTVF was used by teacher and student pairs where the teacher worked alongside their student as a shared experience. RTVF was applied in order to improve student learning and performance in articulation as demonstrated by the left hand legato for Alberti bass, finger legato between chords, left hand arpeggio, and both hands chord attack and release, as well as melodic accuracy which helped students to avoid missing notes. Post-hoc visual feedback was used by the participants in shared experiences when the teacher worked alongside the student. Post-hoc feedback in normal mode was used mainly to focus on articulation, such as left hand legato for Alberti bass, and rhythmic accuracy in respect of the rests between music sections. The application of silent post-hoc visual feedback focused on improving student learning and performance for dynamic balance between the right and left hand. The additional visual feedback was considered to have been applied when teacher and student pairs used it with a clear performance goal in order to improve student learning and performance.

Evidence regarding the application of additional visual feedback can contribute to its potential use for piano learning and teaching. For instance, it was shown how teacher or student can identify and relate the technology, such as the sizes and colours of MIDI notes, to musical performance parameters, including articulation, dynamics, and rhythmic and melodic accuracy, as well as pedalling. Improvement in student learning across the two lessons also indicated how additional visual feedback can bring change to the piano lesson. The application of real-time or post-hoc visual feedback to piano learning and teaching demonstrated how to provide clearer and well-defined lesson foci to improve student learning and performance of particular musical performance parameters. Furthermore, it is argued that even when there is no clear focus to the application of post-hoc visual feedback it can nonetheless be used to augment the listening experience in order to encourage more attentive listening to musical performances. Evidence indicated that the application of additional feedback has the potential to enhance conventional HE piano studios by supporting it and expanding it into a transformative pedagogical approach with clearer and well-defined lesson foci. In Chapter 10, interview QDA findings are discussed.

10 Interview QDA: perspectives of participants across case studies

10.1 Introduction

This chapter discusses interview QDA findings. Interview data consisted of a total of twelve semi-structured interviews: two interviews were conducted with each of the six participants just after each piano lesson. A follow-up question with each of the three teachers was also conducted by e-mail in order to gather their insights after a period of time had elapsed. The interview QDA focused on participant self-reports which could complement or contradict findings from the video QDA, including MIDI QDA, which were the main sources of data in this study. Interview QDA investigated participant perspectives on several aspects related to the application of technology-mediated feedback in a higher education piano studio. In the first interview, all six participants, three teachers and three students, were asked about their personal and music background, experience in the piano studio in the context of the current study, and their previous experiences with music-related technology. This could have been either in their music careers or in the application of music-related technology in their previous music lessons. For ethical reasons, information about their personal background is not reported since this study supports the anonymity of the participants as agreed in the consent forms (see Appendix 5). Participant perspectives on the application of technology-mediated feedback in lessons were also examined in the interview QDA. Interviews also included discussions of teacher and student technology-use preferences for auditory or visual feedback in real-time or post-hoc, their views on change in learning and teaching, and on teacher and student consciousness of student performance outcomes. Findings from the interview QDA also reveal teacher and student views on their experience when technology is applied in a piano studio setting. Findings from the interview QDA clarify those from video QDA observations and MIDI QDA of this study, and are discussed below.

10.2 On the ideal lesson

Interview QDA revealed participant perspectives on what an ideal lesson would be for them. Perspectives on the ideal lesson in case study A seem related to the effectiveness and meaningfulness of teacher feedback rather than direct instructions. It may be for students A, B and C that effective and meaningful teacher feedback prompts them to reflect on their own practice and perform the piano piece with a real understanding of those aspects which need to be improved. Interview transcripts of teachers and students in case studies A and B indicate the ways in which an ideal lesson is constructed through collaboration and reflexivity:

> T: I think it's a lesson that the student has to leave the classroom, with … with a very clear idea of what … what is the work that [the student] will do […] Well, …I think it's a lesson that also makes the student think, because it's no use you tell the student only by giving instructions, a recipe … (Teacher A)

> S: Well …well, I think there must be a lot of dialogue between teacher and student, to know …what are the goals that the student wants to achieve, you know, so [the student] can leave satisfied, and that the teacher could assist… in what [the student] would like. […] I believe that the best way is you use means that the student can develop more and more on their own, that they can get solving their own problems, and […] can have the ability to perceive [themself] in what [the student] can improve, and also have the ability to know what [the student] can do to improve. (Student A)

> T: I think the ideal lesson is this, when the student … is thinking along with you, is investigating, and … I think for me the ideal lesson is this, in which there is a joint research. (Teacher B)

> S: Oh, I do not know, "an ideal lesson"? I think perhaps that a lesson where there is this exchange between teacher and student, because[…] when you can understand the language, I think, of the teacher, when you can understand what [the teacher] wants musically […] Yes. You receive this information [from the teacher], and return to [the teacher] with the music, right? (Student B)

However, in case study C, the perspective of an ideal lesson seems related to and largely dependent on the teacher and lesson structure rather than a collaborative and reflexive piano lesson environment. These views are expressed by the teacher and student as follows:

> T: So, I like to share my class in three … in three stages […] like a triad so you know: the technical and instrumental issue of repertoire; [sight] reading, even if it has to be something detached; and the issue of music appreciation. I think trying to get these three things, you know? (Teacher C)
>
> S: I think one lesson is ideal when … well … the teacher sees the difficulty of the student and … well … and [teacher C] tries to solve that difficulty in the lesson. (Student C)

Investigating perspectives of an ideal lesson might reveal what lies beneath the lesson, something which is not always immediately apparent to an observer or researcher. Awareness of what an ideal lesson should be for the teacher and student might reveal the type of teacher-student relationship in lessons; it may suggest the extent to which the teaching is primarily concerned with the transfer of information and is therefore teacher dominant, or transformative, as characterized by collaboration between teacher and student. Participant views on an ideal lesson uncovered through the interview QDA reveal that case studies A and B adopted a transformative teaching approach, whereas in case study C a more information transfer-based approach was adopted, where the teacher dominates the lesson.

10.3 On real-time visual feedback

Interview QDA suggested that RTVF was applied in a very particular way by certain participants, but not all of them. For example, student A and teacher and student B seemed to have understood the application of RTVF, and perhaps considered it meaningful for specific purposes in their lessons. Student A reported that he had used it for self-monitoring. Teacher B reported the use of RTVF with student B. However, teachers A and C and student C did not appear to have engaged with the application of RTVF.

Students A and B reported having used RTVF when working on articulation. However, the application of RTVF varied in terms of the specific aspects of articulation to be improved in their playing, according to each participant. Student A used RTVF to improve left hand articulation, while teacher and student B used it to improve articulation, specifically legato between chords in the right hand, and chord attack and release in both hands as illustrated:

> S: When I started playing, I soon realized the difference on the left hand, that the notes were shorter [than before]. This was what I wanted to do anyway. So it helped me to see in real-time, right, what the outcome was (laughter). (Student A, interview after lesson 2)
>
> S: With the technology you can see that I didn't play the right thumb [note attack] at the same time [if compared with the other fingers]. Then the graph shows, I was trying to fix what that finger [thumb] was not doing. (Student B, interview after lesson 2)
>
> T: When we spoke of articulation, at a given time the chords were not played legato, the tension of harmony and resolution could be seen on the graph… in fact [the student] was playing legato by using the pedal and not by using the finger. (Teacher B, interview after lesson 1)

Apart the use of RTVF being beneficial in piano lessons, its application also disrupted performances to some extent. Students A and B, and teacher B commented on several disadvantages. RTVF required adjustment to the new experience; it also distracted students during performances by causing memory lapses.

> S: I think there are times when perhaps it could have disturbed some things, you know. (Student A, interview after lesson 2)
>
> S: That also made me have a lack of memory to some extent, […] because I was paying attention to a new tool, you know. (Student B, interview after lesson 2)
>
> T: Sometimes [the student] dispersed a bit with that [real-time visual feedback], but it's a matter of habit as well. (Teacher B, interview after lesson 2)

Disadvantages of using RTVF were reported in the interviews since its application could distract students (teacher A) or induce teachers to come to a conclusion about student performance (teacher C). Teachers reported avoiding use of RTVF so to prevent external influences on their perception and teaching. Student C also reported being unable to focus simultaneously on their own performance and the RTVF. Self-reports of difficulties are illustrated below:

> T: I cannot stand looking at that. I cannot, because then I cannot pay attention to the sound. (Teacher A, interview after lesson 2)

> T: At first I started to look at the screen and such to see, but I didn't […] I was looking at [the student's] hand too much, something that I don't usually do. I avoid looking at the [student's] hands, I avoid trying to let me … well, to be induced to see… I'd rather hear it. (Teacher C, interview after lesson 2)

> S: Well … I, I mean. I got to notice it, but I think that when … at the moment when I'm playing you [I] cannot notice it so much. (Student C, interview after lesson 2)

Perspectives on the application of RTVF are diverse since they depend on engagement with the visual feedback, while focusing on student performance as well. One advantage of RTVF according to participant reports is that students can perceive aspects of their own performances whilst playing. A disadvantage of RTVF is that students can be distracted from their playing by experiencing memory lapses, and making mistakes. Another disadvantage is that teachers can also be distracted or induced by an external source to provide feedback on student performances since they need to combine their focus on the visual feedback and student performance at the same time.

10.4 On post-hoc auditory feedback

Participants felt that the application of post-hoc auditory feedback was an effective tool. Overall, participant perspectives on the use of post-hoc auditory feedback seemed to be unanimously positive. Participants agreed that such additional feedback was beneficial since students were solely listening, rather than playing and listening at the same time. This contrasts with what was reported for the application of RTVF.

Post-hoc feedback which included simultaneous auditory and visual feedback might have promoted more attentive listening to student performances during piano lessons. The statements below serve to illustrate these views:

> S: Oh, it was used to listen more carefully […] As I said, you know, you can pay more attention, you are more focused on listening, and not on playing and listening at the same time. (Student A, interview after lesson 2)

> T: So if listening … listening to a 'playback' clarifies that sort of thing a lot, just the fact of hearing the 'playback', you know? (Teacher A, interview after lesson 2)

> S: Well … and I think that being able to listen back immediately like this, this is something that helps you a lot, you know, because I think you correct yourself, I find it easier to understand what I did. (Student B, interview after lesson 2)

The advantages of using slower post-hoc auditory feedback were also reported by participants:

> S: When we think it is almost accurate when … well … decreasing the tempo [of the recorded performance-related data] to see how it was, we see that was very imprecise. (Student C, interview after lesson 2)

> T: This thing of slowing down was also something that we ended up using […] to work on the issue […], the rhythmic precision, rapid notes. That's what was most interesting. (Teacher C, interview after lesson 2)

The application of post-hoc auditory feedback either in the original tempo or at a slower tempo was reported by participants as being useful for the improvement of rhythmic accuracy. A variety of examples were given: silences between phrases, case study A; tempo relations between music sections, case study B; and rhythmic accuracy for musical figures such as triplets and dotted quavers and semiquavers, case study C. Participant excerpts illustrate the issues covered:

> S: Oh, we worked on this issue of the silences, you know, for example, which were too short in the case. This enables us to understand by listening, you know. (Student A, interview after lesson 1)

> S: Yeah. So … there was … well … when we … at the beginning of class [teacher B] talked about the tempo of the opening, you know, and then [teacher B] talked about the second part when there is the exposure an octave lower. (Student B, interview after lesson 2)

> S: Um … was also that … that … that helped rhythmic imprecision, well … because … well… first it began with … the alternated rhythms, right. It started with triplets and then there was no longer a triplet, and then it came back to triplets. (Student C, interview after lesson 1)

Post-hoc auditory feedback seemed to be useful in allowing participants to listen back to their own recorded performance-related data. Participant views on its use were positive, particularly with students, since it was easier to identify issues raised when listening back than when listening while performing. The usefulness of post-hoc auditory feedback can also help students become more independent in their learning since it enables them to perceive and reflect on the successful aspects of their performances, and on what needs improving.

10.5 On post-hoc visual feedback

The use of post-hoc visual feedback was reported by participants during interviews. In case study A, both teacher and student reported making sense of the additional visual feedback in terms of MIDI parameters available to them, not only by identifying the music score as a graphic visualization but also by making sense of what happened in terms of performance.

> S: The issue of MIDI was also very interesting, because it is pretty straightforward, it is very objective, you can clearly see, you know. The coolest thing is that it is very clear, you know, it is there, you know. You see what you did, what you didn't do, there's no way to deny it, right? It is recorded there, graphically, if you play the note it will appear, and if you don't play it, it will not appear, right. If you played strong it is shown with one colour, if you played it weak, it is shown with another colour. So it's well … I think it helps you a lot to see […] I think the visual shows it faster to you. (Student A, interview after lesson 1)

> T: But the 'playback', with those visual graphics, explains a lot, right? (Teacher A, interview after lesson 1)

Differences in perception of MIDI parameters were very clear when comparing teacher and student interview data in case study A. While teacher A readily perceived and interpreted variations in colour, student A perceived differences between key velocity numbers more readily. This evidence might be related to individual differences between participants regarding types of visual feedback, as reported below:

> S: Well… I think it was very interesting, because sometimes you cannot differentiate one colour from another very well, and the number is quite accurate, you know if it was one-tenth more than the other, you can see the number. (Student A, interview after lesson 2)

> T: Yeah, and then today it was helpful [the application] of … of colours and numbers in this part, it was also useful for … […] We take a little bit of time to [realize] the numbers […]. The colour is visualized much faster. You look there, it became red [saying ta-ta-ta]. The number… you take longer to read each number, our brain takes longer to … well… I think they are two different things, you know. (Teacher A, interview after lesson 2)

In case study B, participants seemed to recognize the additional visual feedback as another form of the music score. It was seen as related to the piano performance by displaying on the computer screen what had been played. In addition, student B seemed to have perceived the visualization as a representation of their performance. Teacher B also reported that the student had made sense of the visual feedback as a way to analyse the musical performance parameters through the keyboard activity of the recorded performance-related data:

> S: It has the graph, right, which is … shown. And this graph shows the details quite well, […] Yeah. It gives…, you can see a music score, right? A music score appears of what you have played, right? Of what you did, right? You can identify everything that you played. (Student B, interview after lesson 1)

> T: When you look at the graph, all those musical features get kind of frozen [stagnant] because there is a, there is a … a graph with…the issue of the keyboard mechanics that is a very real thing. Do you see? So I think this is … it's a good thing. (Teacher B, interview after lesson 2)

In the same way, in case study C, engagement with the additional visual feedback enabled participants to see the relationship between the musical notation and the visualization on the computer screen. The level of engagement of teacher and student C with the visual feedback prompted them to identify another type of musical notation on the graph presented.

> S: And you could see on the graph—at least I could easily identify and relate to the music score. I could clearly see the parts and I could see what needed improvement. Even with the frozen graphic I could … well … it is clear the duration and the intensity at which it was played. (Student C, interview after lesson 2)

> T: And, in most cases it was very easy because you really see—it is what I told you last week—you see another type of music score, another type of notation which perhaps is even more realistic. (Teacher C, interview after lesson 2)

The extent to which the graphic visualization represented the musical performance parameters related to the recorded performance-related data was raised by teacher C. The teacher doubted the reliability of the visual feedback, feeling that it might not show what performance really was. This doubt indicates the challenge faced by teachers and students in how to apply technology-mediated feedback in a meaningful way. It might be worth examining further the extent to which the visual feedback in colour actually reflects the dynamics of piano performance. However, if the visual feedback in colour assists the teacher in making the student aware of their performances, the additional visual feedback has been useful.

> T: I do not know to what extent the colour gradient [nuances] reflects exactly what we're hearing—this is what I'm curious about you know. (Teacher C, interview after lesson 1)

Post-hoc visual feedback seemed related to specific musical performance parameters when applied in the piano studio. Most of the musical performance parameters were related to tempo, dynamics, phrasing, fingering, motor control issues, and technique. The relation between technology, MIDI parameters, and musical performance parameters was reported by the participants when they used visual feedback with a clear purpose:

> S: Oh, I can see you know, the issues of tempo, silences, you can see the issue of dynamics, you can see the direction of the phrasing, if it is crescendo or decrescendo, to see the accents … You can see everything there in the graph. (Student A, interview after lesson 2)

> S: Well, … it was useful to … to see the thing … we were talking about the third finger of the left hand, which was not working out [for the arpeggio], it was being held a little bit, and then the graph showed the note that the third finger played was longer. (Student B, interview after lesson 2)

> S: I could see clearly on the graph where it was even darker than … than … than the rest of the phrase, you know. When it's lighter it is weaker, which indicates that you have to be clearer when ending a phrase (laughter). (Student C, interview after lesson 2)

All participants reported to have identified the music score through the visualization of performance on the computer screen. This suggests that participants made associations between technology, MIDI parameters, and music score in all three case studies. However, application of post-hoc visual feedback was useful when participants were able to make associations between technology, in terms of MIDI parameters, such as MIDI notes colours and asynchrony and musical performance parameters, for example, dynamics and articulation. Specific aspects of student performances seemed to benefit from its use when worked on alongside their teachers, but this varies due to the individual differences across participant pairs.

10.6 On musical performance parameters

Participants reported on particular musical performance parameters which were worked on when using technology-mediated feedback to improve student performance. Use of technology-mediated feedback was unanimously agreed across case studies to make lesson focus clearer for rhythmic accuracy and dynamics in student performances (see Sections 10.3, 10.4 and 10.5). Case studies A and B shared the same view that a clearer lesson focus was achieved for articulation and tempo between musical sections. Phrasing was also reported alongside rhythmic accuracy and dynamics; this indicates these parameters have relationships. Further investigation on phrasing is suggested when using technology in piano studios.

Although the participants identified a range of musical performance parameters which benefited from the application of technology in the piano studio, both teachers and students appeared to be aware of the limitations of using the digital piano in the research study beforehand. There seemed to be a common belief among the participants that a digital piano does not give a good response for particular musical performance parameters. The teachers might have avoided commenting on certain musical parameters because of the digital piano limitations. Self-reports illustrate the limitations the digital piano in this study:

> S: This is the issue of having to use a digital piano, you know, because … because, then, you lose some… of the sensitivity of the acoustic piano keys, even the sound response, and everything else, you know. (Student A, interview after lesson 2)
>
> T: The only thing that maybe … the pedal, you know, we tried to put it, right, but … it really does not have the same sensitivity there [as the acoustic piano]. (Teacher A, interview after lesson 2)
>
> T: But that digital pedalling is one more thing … it is rawer, like this, right? It has no harmonic as such. (Teacher B after lesson 1)
>
> S: One thing. I've already… well, I do not… the sonority, sometimes, it [digital piano] cannot change the timbre; the sound is always the same, right. (Student C, interview after lesson 1)
>
> T: I think it just is not great because the instrument itself is very limited, the [digital] piano. […] The lack of harmonics bothers me, it seems that I'm dealing with, really, with something which is made of plastic, you see. (Teacher C, interview after lesson 2)

Participant statements suggested that the musical performance parameters associated with limited response on the digital piano are sonority, touch, tone quality, and pedalling. These limitations occur mainly because of differences in the mechanics of digital pianos in comparison with acoustic pianos, and also in the resonance of their harmonics.

10.7 On conscious-awareness of performance outcomes

Enhancing awareness of student performance was common to participant reports in the interview QDA. According to the participants, when technology was applied in the piano studio conscious-awareness of performance during piano learning increased when comparing the intended performance with actual performance outcomes. This raised conscious-awareness might depend on the technology-mediated feedback used, visual or auditory, and whether it was given in real-time or post-hoc.

Conscious-awareness of piano performances would clarify whether, and to what extent, the intended performance outcome was different or similar to the actual performance outcome. In this sense, once a student is aware of their own performance outcomes by comparing the intended performance and the actual one, it will be easier to see whether there is a need to improve the performance. This would be possible when listening back to the recorded performance or seeing the visualization of the recorded performance-related data. The technology which was brought to the lesson as an additional tool possibly made teacher-student pairs more aware of the learning and teaching involved in piano performance, as suggested by self-reports:

> S: Sometimes you know in your mind what you want to do, […] but sometimes you do not realize exactly what you're doing in practice […]. So, when you hear, you can clearly see what you are doing and what you're not. (Student A, interview after lesson 1)

> T: For example, that issue of articulation which I had spoken about lots of times to [name of student A] which is "okay, you are holding these notes, but do you want to hold them? Do you hear the effect you are making?" And [the student] did not realize what [they were] doing. And then there I didn't need to even talk, right? [The student] saw it, [and the student] realized, right? […] Well… because the visual is a … is another channel, right? Sometimes the sound is not enough [to make

> someone to realize], so suddenly the visual makes you hear things that maybe you were not listening to, right? (Teacher A, interview after lesson 1)
>
> S: I think you can perceive yourself much better as a student, I think, [you can] realize your own performance. (Student B, interview after lesson 1)
>
> T: Sometimes students need to hear themselves in order to realize one thing they did and they did not notice […] … so they can understand what I'm talking about. (Teacher B, interview after lesson 1)
>
> S: After I saw the graph, I think it explained quite clearly that I was trying to fix something that was already right. […] You can already see the problem. (Student C, interview after lesson 1)
>
> T: Somehow, the penny dropped, you know? […] [The student] began to perceive things [they] could not perceive in an auditory way anymore. (Teacher C, interview after lesson 1)

The use of this type of technology-mediated feedback might have made not only the lesson focus clearer but also which performance issue needed improvement. Listening back to self-performances without playing might be one activity that is uncommon in piano lessons. However, listening back to recorded performance-related data might have had an impact on student conscious-awareness of their own performances, and subsequently on their learning process. Once technology-mediated feedback had been used in the piano studio, it provided one more available tool to help make teachers and students aware of the student performance by comparing the intended and actual performance outcomes through additional visual or auditory feedback.

10.8 On change in the learning process

Teacher and student perspectives supported changes in student learning when technology was applied in the piano studio, apart from teacher C who showed reservations. All three students seemed to agree that the playing back of recorded performance-related data provided an additional learning tool through visual and auditory feedback. Two of the three teachers seemed to have agreed on the positive changes to student learning: enabling greater student awareness of their performance, adding a new way of practising, and both augmenting and accelerating the learning process.

Student perceptions of change in their learning when using technology-mediated feedback were positive. Student A stated that technology-mediated feedback added a new way to learn by offering the facility to visualize performance which speeded up the learning process. Student B affirmed that listening back to their own performance-related data and then re-performing, rather than listening to the teacher playing enhanced their learning process. Student C asserted that the technology provided a clearer lesson focus on the improvements needed. Student views are illustrated in the following comments:

> S: Because you're seeing, you know, what you've played, normally you just listen to, you know, the music. […] You see the music in a graph, right, so it's a new way of learning, of course, by looking at the graph. (Student A, interview after lesson 1)
>
> S: Because it was a different way, you know, because I heard myself doing one thing and I wanted to correct myself, right! [I wanted to] do what I'd done again. It's different to hear the teacher playing, and you go there … and try to do it, right! (Student B, interview after lesson 1)
>
> S: So, I think I could walk [develop] faster, you know, because in … without the technology sometimes you lose some things which we cannot focus on […] And by seeing, we focus well, […] Sometimes, well, you see the problem, well … for what I realized, you know, when I visualize it seems that it makes it easier to solve. (Student C, interview after lesson 2)

Teacher perceptions of change in student learning when using technology-mediated feedback were largely positive. Teacher A asserted that visualization of performances enhanced student perception. Teacher B argued that the technology promoted or assisted student investigation of their own performance. However, while teacher C thought that the ability of the technology to show clearly where a performance problem lay was a catalyst for learning, it could never replace student perception. The excerpts below illustrate the views of teachers on change in the learning of their students when technology-mediated feedback was used in lessons:

> T: I think it certainly showed things that […] [the student] was not able to realize. (Teacher A, interview after lesson 1)
>
> T: It is interesting to note that [the student] investigated without the technology, I mean, [the student] left here with the reference of the technology and [the student] studied without it, and [the student] returned to check if there was a difference. (Teacher B, interview after lesson 2)
>
> T: I think that it [technology] tends to accelerate the learning process […] No … it wouldn't replace [student] perception, for example. [The student] has to realize without it. […] The way to learn, no, because the process ends up being the same, you know. […] What has changed is that story you can perceive in a more … exaggerated way where the specific problem was. (Teacher C, interview after lesson 2)

Overall, according to teachers and students, technology-mediated feedback changed the learning process. Student learning was accelerated and specific lesson foci were clarified. These changes were effected mainly through students being able to listen back to their recorded performance-related data, which in turn allowed them opportunities to repeat the performances immediately afterwards.

10.9 On change in teaching approaches

Perspectives on changes in teaching approaches seemed to diverge when comparing teacher and student views of technology-mediated feedback use in the piano studio. Although most participants agreed on the changes in student learning, their views on changes in teaching approaches differed. While students perceived a change in teaching styles with the incorporation of a new technological tool in piano lessons, teachers did not seem to perceive a change in their own teaching approaches when technology was applied, or they did not appear to feel or admit to change over a very short period of time.

Change in teaching approaches associated with technology-mediated feedback was reported in student interviews. Students A and C asserted that they were able to see clearer details when technology was used, which thus enabled teaching to become more focused. Student B reported that the technology added a new tool when listening back to recorded performance-related data during the lesson, which facilitated teacher-student discussion. Student C maintained that technology-mediated feedback use contributed to a quicker teaching process. The interview excerpts below illustrate the views of students on change in teaching approaches when technology-mediated feedback was used in their lessons:

> S: We took advantage of the resources that we had to see very clearly, certain details that … that in a class without technology are more in the air as well, are not so clear. (Student A, interview after the lesson 1)

> S: Yeah, it changed a bit because we have a new tool that we don't commonly have in the classes, you know. […] So it changed a bit because we had the methodology of "hearing" soon after [playing] and commenting on it. (Student B, interview after lesson 2)

> S: I think that it helped to shorten the time to realize … well … the exact point of the piece where we need to fix it. (Student C, interview after lesson 2)

Teachers A, B and C thought that the use of technology-mediated feedback over two piano lessons was insufficient to make a change in their teaching styles, since most of the aspects involved in the lessons were similar to those in a conventional piano lesson. However, teacher B maintained that technology-mediated certainly shortened the time in making students aware of their performances. The excerpts below illustrate the views of teachers on changes to their own teaching approach when technology-mediated feedback was used in their lessons:

> T: I cannot answer as well; with two classes it's difficult. […] things that I did here are things I deal with even in [normal] class. (Teacher A, interview after lesson 2)

> T: Then suddenly, so I …I do not know if something has changed, but suddenly it is a way of claiming something, you know,
> because …because without the graphic, well … maybe it takes a little bit

> more time for the student to realize, you know. (Teacher B, interview after lesson 2)
>
> T: I do not think it would be very different from a conventional class. At least here for me it was not; for me it was quite normal. (Teacher C, interview after lesson 2)

Teachers and students appeared to have different perspectives on change in teaching approaches. According to students the lesson focus was clearer, while for teachers the lessons were quite similar to a normal piano lesson without technology use. However, all participants agreed that in some way the use of technology-mediated feedback accelerated the teaching process in their lessons.

10.10 On teacher and student feedback

Teacher feedback was investigated through analysis of the semi-structured questions that teachers and students were asked regarding their usual teaching style. Reports by participants illustrate perspectives on teacher verbal and non-verbal feedback in conventional lessons without technology.

In case study A, according to their student, the teacher seemed to give more verbal feedback than non-verbal feedback. In addition, teacher A also self-evaluated their playing style when demonstrating something to the student by exaggerating the performance.

> S: [Teacher A] does not usually play music, no. [Teacher A] usually […] often talks indeed. […] [Teacher A] used to imitate us on the piano, to demonstrate what we are doing, the music piece, exaggerating a bit for us to realize what is happening, and we even know, to see if this is what we want. (Student A, on teacher A, feedback, interview after lesson 1)
>
> T: When I did [play], I exaggerated the phrasing a little bit more then [student A] actually saw [perceived] it. (Teacher A, about their own feedback, interview after lesson 2)

In case study B, the student highlighted the care that teacher B took to respect the personal artistry of the student, something which was also acknowledged by teacher B.

The intention of teacher B when playing was not to make the student imitate the performance, but to offer the performance as an inspiration for the student to change their own performance.

> S: Yes. [Teacher B] plays, you know. It…, it happens in our class, and … but … to be honest [teacher B] does not play so much, [teacher B] talks much more about … about points, like this, about specific points. (Student B, on teacher B feedback, interview after lesson 1)

> T: Actually I do not want the student to play like me, I want [student B] to listen more than imitate, right! [Student B] listens, and is inspired and tries to do it [their] own way it, but within that … that aspect of music that we are focusing on. (Teacher B, about their own feedback, interview after lesson 1)

In case study C, the student stated that the teacher usually plays a lot not only by imitating student playing but also by modelling, that is, playing a model for the student to imitate. In order to teach student C how to study, teacher C claimed that playing alongside or in alternation with the student was a useful approach. Both teacher and student C commented on the extent of feedback by playing:

> S: [Teacher C] imitates what I'm doing, you know. Sometimes [teacher C] plays an excerpt which is not good, [teacher C] plays, [teacher C] plays for me … such as in an exaggerated way. [Teacher C] says that it was not how I'm playing, but [teacher C] exaggerates it to see how to … to make me to pay attention to what it is that's coming out wrong. And then [teacher C] plays it again to show how it has to be played, how it has to sound. (Student C, on teacher C feedback, interview after lesson 1)

> T: I studied with [student C], basically that's it. And I teach [student C] to study, you see? I ask [student C] very little such as "Look, do it," or to see the model. […] I propose—as I told you about—to play with [student C] a lot, right. (Teacher C, about their own feedback, interview after lesson 1)

Through the interview QDA, it was possible to observe whether the teachers were aware of student feedback during their lessons. Teachers A and B gave examples of student feedback when answering semi-structured questions. The data elicited suggest that in case studies A and B, the teachers seemed to be aware of the importance of student feedback:

> T: [Student A] even showed to me: "the note has to have the same length of the silence but the space is bigger …" [student A] saw that. (Teacher A on student A, interview after the lesson 1)

> T: I saw that [student B] was playing and looking at the same time to see if that happened, and [student B] still said: "they never fall completely together, millimetrically equal, but you can improve" you know? (Teacher B, on student B, interview after lesson 2)

Teacher C did not seem to report on student feedback to the same extent as teachers A and B. The interview excerpt below illustrates teacher lack of awareness of student feedback:

> T: You saw that there was one moment I asked [student C] "So, what are you thinking? What happened there? Yes, but you know where exactly was it?" It was when [student C] placed their hands … [Student C] realized, but he did not know exactly where, you know? (Teacher C, on student C, interview after lesson 2)

Perspectives on teacher verbal and non-verbal feedback in conventional lessons suggested that the teachers in case studies A and B were similar as they engaged in more verbal feedback than teacher C who relied to a greater extent on non-verbal feedback and modelling.

10.11 Teacher follow ups

A follow up question was asked four months later, in May and June 2014. It was sent to teachers from all three case studies to gather their further insights after a period of time had elapsed. The teachers were contacted by email and asked to give their reflections on the effect of the technology-mediated feedback in higher education piano learning and teaching (see Table 10.1):

Table 10.1 Teacher responses to follow-up questions in each case study

Follow-up questions	It would be very helpful if you could email me your response to the following question: On reflection, what difference (if any) has this experience of using technology in the piano studio made (a) to your teaching and maybe (b) to your student's learning?
Teacher A	I am not sure how to answer these questions. I think the experience [in the research project] was quite short to provide a real difference in my teaching. I don't have anything to add beyond on what we have talked after the sessions.
Teacher B	(a) In teaching: the ability observe graphically and to note details related to piano performance, especially on issues related to tempo, dynamics and articulation (b) In learning: the chance to hear and see graphically more accurately what is proposed in the class.
Teacher C	As pictured during the sessions, I believed I would use the technology in a very punctual way, probably setting a gap [between the lessons], maybe of two months between the first and the following applications of technology in order to make the student to realize themselves what technology would merely confirm or reinforce more clearly. Thus, I would try to avoid the use of this piece of equipment into a "crutch" way which would be extremely harmful in the course of time. As a teacher, some points on dynamic and values became more evident, and it also enabled a greater clarity of communication between me and my student, since the graphs reflect, in a visual way, the sound results. In the case of student learning, I start from the same principle. The possibility of the students "see the sound" enabled a faster feedback of the proposals suggested by me.

Findings of the follow up suggested that most teachers retained the same perspective they had shown in the interviews. Teacher A claimed to have nothing to add to the previous self-reports in the interviews. Teacher B emphasized that visual feedback seemed to be beneficial in piano learning and teaching especially in terms of the following musical performance parameters: tempo, dynamics, and articulation. Finally, teacher C seemed to have recognized the advantages of visual feedback in the piano studio mainly for dynamics and rhythmic accuracy or note duration.

10.12 Summary

Interview QDA revealed the perspectives of teachers and students with regard to the use of technology-mediated feedback in higher education piano studios for two lessons. It aimed to supplement the findings observed in the video QDA. Interview QDA findings supported the video QDA findings regarding participant perspectives on additional feedback, namely, visual and auditory feedback in real-time and post-hoc. Participant views diverged on the application of RTVF. Three participants agreed on its benefits and three argued against the usefulness of this tool since it had been found to distract teachers and students during playing. There was almost unanimous agreement on the use of post-hoc feedback. Participant perspectives on post-hoc auditory feedback supported the benefits of listening back to performance-related data in order to compare intended and actual performance outcomes which could be achieved following student playing. Participant perspectives on post-hoc visual feedback seemed related to the way they engaged with technology, and the extent to which they associated technology, such as MIDI parameters, with music, in terms of music score, or performance parameters, for example dynamics, rhythmic accuracy, articulation, and tempo.

Interview and video QDA findings were complementary with reference to participant perspectives on the conscious-awareness of students regarding their own performances and views on change in learning and teaching approaches. Teachers and students stated that differences between intended and actual performance outcomes could be perceived by listening back to or seeing the visualization of performances. Greater conscious-awareness might promote change in student learning and performance and so reduce differences between intended and actual performance outcomes. Participants acknowledged changes in learning across case studies, while they had discordant views on change in teaching approaches. Teachers did not see themselves as changing their teaching styles since the content of lessons was very similar to conventional lessons without technology. Students reported that different teaching styles were adopted since they could listen to their recorded data while not playing. Overall, participants reported greater lesson focus, enhanced conscious-awareness of piano performance outcomes, and faster learning and teaching process when technology-mediated feedback was applied in higher education piano studios. In Chapter 11, the multi-method QDA findings are reviewed and discussed.

11 Summary and discussion of data analyses

11.1 Introduction

In this chapter, findings of the multi-methods qualitative data analyses of the current study are discussed. Overall findings from video observation, technology-generated MIDI data evidence, and interviews are revisited and compared in order to examine whether (and how) they complement or contrast with each other. First, findings of video QDA which revealed types of interpersonal feedback between the participants themselves, and between the participants and technology, are re-examined. Types of additional auditory and visual feedback which were available and were related to the application of additional technology in this study are also discussed through the findings of microstructure analysis of musical behaviour. Second, findings from MIDI QDA, which revealed the different uses of additional visual feedback in piano studios, are set out. Third, findings from interview data relating to participant perspectives on the use of technology-mediated feedback are compared with the findings of the video QDA including MIDI QDA. Interview QDA was seen to have supported video QDA for the overall pedagogical use of technology-mediated feedback in lessons. Findings from the interviews thus complemented those from video QDA. These suggested that positive changes were noted in learning and teaching, with accelerated learning and similar and different pedagogical approaches, and that student conscious-awareness of performance was enhanced. This chapter also revisits the literature review, and seeks to connect empirical findings with the theoretical framework for this study.

11.2 Video, MIDI and interview QDA: An overall QDA approach

This study investigated the nature of feedback in piano learning and teaching with the application of technology-mediated feedback, including its pedagogical use, and its effectiveness in a higher education piano studio. Multi-methods qualitative data analyses involved video QDA of different approaches including MIDI QDA, and interview data. The video QDA approaches contributed to in-depth qualitative analysis of the data available to participants, viewed through my perspective as the researcher.

The first approach to video QDA addressed findings for teacher and student verbal and non-verbal behaviours (see Appendices 7 and 8). Three categories of participant behaviour were analysed: talk, playing, and verbal and non-verbal feedback. Talk involved the sum of all verbal behaviours, whilst playing encompassed the sum of playing as a non-verbal behaviour. Verbal and non-verbal feedback types were generated from the cross-tabulation between behaviours (verbal and non-verbal) and music performance parameters. Each of these feedback types related to the three main areas of musical performance parameters, namely music, performance, and technology (see Chapter 6). The second video QDA approach focused on the pedagogical use of technology-mediated feedback. Specifically, common patterns of the application of technology generated additional visual and auditory feedback, in real-time and post-hoc, were analysed (see Chapter 7). The third approach of video QDA involved microstructure analysis of musical behaviours (see Appendices 11 and 12). The musical behaviours analysed were: musical practice, or playing; and listening back while not playing the piano. Musical practice described the moments of teacher or student playing. Listening back described moments of myself playing back recorded performance-related data generated by teacher or student playing. This microstructure analysis of musical behaviours revealed additional auditory feedback types which were available in lessons such as post-hoc auditory feedback at the original or slower tempo (see Chapter 8). The fourth approach involved qualitative analyses of the MIDI data generated in lessons. Specifically, MIDI QDA provided the analysis of piano roll visualization and MIDI data and revealed the use of additional visual feedback in piano lessons (see Chapter 9). The data types indicate the effective application and/or potential usefulness of technology-mediated feedback.

The interview QDA addressed findings that were supportive of video QDA findings in this study (see Chapter 10). The perspectives of teachers and students on the use of technology-mediated feedback were reported in the interviews. Interview QDA supported video QDA regarding participant views on the pedagogical uses of technology-mediated feedback in their HE piano lessons. Interview QDA complemented video QDA with regard to participant background information, piano-related experiences, and, more significantly, their perspectives on change in learning and teaching, and enhanced conscious-awareness of student performance. Most importantly, interview QDA findings bring to the research what I cannot know from only observing videoed lessons, since the interviews provide participant self-reports on their individual experiences and backgrounds prior to the research project. The match or otherwise between video QDA, encompassing MIDI QDA, and interview QDA regarding the application of technology-mediated feedback in HE piano lessons is discussed in the following sections.

11.3 The nature of feedback when technology is used in HE piano studios

In the current study, it is argued that two types of feedback are considered to be present when technology-mediated feedback is used in HE piano studios: intrapersonal and interpersonal feedback. *Intra*personal feedback was seen to be intrinsic to each individual participant of this study. Intrapersonal feedback is related to sensory feedback, such as visual, auditory and proprioceptive feedback, and associations between these (Bishop & Goebl, 2015; Brown & Palmer, 2012; Halwani et al., 2011; Moore et al., 2016). Intrapersonal feedback also refers to aspects of conscious-awareness, self-regulatory skills, metacognitive knowledge and sense of self (Acitores, 2011; Damasio, 2012, 2000; Nielsen, 2001; Schraw & Dennison, 1994) which are also part of the internal systems of each participant of this study (see model of intrapersonal feedback in Chapter 3).

*Inter*personal feedback was seen to be extrinsic to each individual participant of this study. It is related to feedback provided by an external source, such as teacher or technology. In this study, the nature of feedback in piano learning and teaching with the application of technology-mediated feedback was revealed through in-depth video QDA of participant behaviours, musical behaviours, as well as through MIDI data. The main participant verbal and non-verbal behaviours were grouped in three categories: talk, playing and feedback. Video QDA findings suggested that teacher talk was predominant across the three case studies, even when technology was applied in lessons, as evidenced in previous studies in conventional piano lessons (Benson & Fung, 2005; Bryant, 2004; Kostka, 1984; Siebenaler, 1997; Speer, 1994). In case studies A and B, student playing was predominant. However, in case study C the teacher modelled a great deal by playing, which is seen as another form of non-verbal feedback. Here, the teacher dominated the lesson by playing as well as talking. Video QDA findings suggest that student playing occurs in response to teacher feedback. This evidence implies a circular or dependent relation between teacher and student, something which concurs with findings of previous research (Burwell, 2010).

Video QDA findings of this study demonstrate that the nature of feedback in a higher education piano studio with the application of technology-mediated feedback was both verbal and non-verbal in three main areas: music, performance, and technology. First, feedback was related to music and included aspects of the musical score such as music structure, harmony and tonality. Second, feedback could refer to performance, including dynamics, articulation, rhythmic and melodic accuracy, and pedalling. Third, feedback embraced technology such as MIDI parameters, MIDI recording versions, and digital piano use.

In this study, the nature of teacher feedback was verbal and non-verbal; this agrees with previous studies (Benson & Fung, 2005; Burwell, 2010; Siebenaler, 1997; Speer, 1994; Welch et al., 2005). Types of teacher verbal feedback encompassed providing information, giving direction, and asking questions. Types of teacher non-verbal feedback included body and head movements, pointing to the score or computer screen, playing, and gesturing. These verbal and non-verbal feedback types could be linked to each of the three main areas, namely, music, performance, and technology, according to teacher and student understanding of and engagement with technology.

In a piano lesson which uses technology-mediated feedback, it is not solely the teacher that becomes responsible for providing feedback. Video QDA findings suggest that students also played a role in providing feedback. In this study, students could feed back on their own performances through verbalized self-assessment and non-verbal feedback, as both their visual and auditory intrapersonal feedback were enhanced. Video QDA findings are in line with those of previous research (Hattie & Timperley, 2007; Magill, 1989; Schmidt & Lee, 2011; Welch, 1983; Welch et al., 2005) which acknowledged that feedback also depends on the internal systems of students. In this study, student feedback in lessons may have occurred due to the application of technology, which can help create a more collaborative environment between teachers and their students which concurs with findings of previous research (King, 2008). The use of technology can also engender a change in learning through the adoption of a transformative pedagogical approach. This approach supports and extends traditional teaching, due to the coexistence of similarities, in terms of music and performance, and differences, in terms of technology, in the lesson context of piano studios which agrees with findings of previous research (Savage, 2007).

Findings of this study agree with previous research which addressed the notion that effective piano learning and teaching with specific feedback (Kostka, 1984; Siebenaler, 1997; Speer, 1994) can in turn improve student autonomy (Creech, 2012). Verbal and non-verbal feedback in this study were linked to music and performance as reported in research on conventional piano learning and teaching, with regard to dynamics, tempo, articulation, and musical structure (Bryant, 2004; Chaffin & Imreh, 2002; Keithley, 2004). Verbal and non-verbal feedback forms in this study were also linked to technology such as MIDI parameters, including MIDI note colours, sizes, and key velocity numbers. These findings suggest that participants were able to make associations between music, performance and technology. Findings of this study agree with those of previous experimental studies which analysed piano performance recordings by associating performance and technology parameters, in terms of MIDI parameters, for example, dynamics and MIDI key velocity numbers, and timing and IOI (Bernays & Traube, 2014; Bresin & Battel, 2000; Palmer, 1989, 1996; Repp, 1994, 1996).

The nature of feedback in this study also depended on the interpersonal feedback between participants and technology. Technology-mediated feedback generated additional sensory feedback, in terms of visual and auditory feedback, which enhanced or augmented intrapersonal feedback of teacher and student participants in their lessons. The pedagogical and potential uses of additional visual and auditory feedback generated by technology in a higher education piano studio are discussed below.

11.4 Pedagogical uses of technology-mediated feedback in HE piano studios

In this study, pedagogical uses of technology-mediated feedback were explored in HE piano learning through an innovative technological tool, one which integrated additional visual and auditory feedback, data collection design, processing, and analysis. Pedagogical and potential uses of technology-mediated feedback in HE piano learning and teaching were revealed through in-depth video QDA, and complemented by MIDI and interview QDA findings. Video QDA findings suggested that additional visual and auditory feedback was available, simultaneously, to both teacher and student in two forms: in real-time and post-hoc, whether or not participants were aware of these facilities. RTVF was available whenever the teacher or student was playing, meanwhile, I was recording performance-related data generated by participants on DAW software. Real-time auditory feedback was not considered additional given that it is available in a traditional piano lesson while the teacher, student, or both participants are playing.

Post-hoc visual and auditory feedback was available whenever I played back recorded performance-related data to the teacher and student, or switched and froze the computer screen in order for participants to read it. Post-hoc visual and auditory feedback could also be used at the original or slower tempo, and in normal or silent modes. Performance-related data was recorded and saved in DAW software, and could then be played back varying in three aspects: the performer, teacher or student; the specific musical excerpt; and the version of the recorded data. The pedagogical uses of additional visual and auditory feedback when technology is applied in HE piano studios are discussed in the next sections.

11.4.1 Additional real-time visual feedback

Video QDA revealed two forms of RTVF use. The first form arose when an individual participant perceived a potential benefit from RTVF. The second form occurred when a shared teacher and student experience prompted the synchronized use of RTVF. In the first instance, the perception of an individual seemed to occur when a teacher or student made sense of RTVF and realized its benefit, despite the unawareness of their respective partner. The first use of RTVF occurred in case study A when the student seemed to have made sense of RTVF in a very subtle way. Student A then used it independently to meet their individual need, in terms of improvement in the articulation of the left hand. This use of RTVF happened even though the teacher did not seem to support the student in using it as part of a clear lesson focus.

In the second instance, the perception of an individual seemed to occur when the teacher or student made sense of RTVF, realized its potential usefulness first and then guided their respective partner to use it together. The second use of RTVF occurred in case study B when the teacher made sense of RTVF, and supported the student in its simultaneous use. This resulted in the application of RTVF with a clear lesson focus, as teacher and student B then used RTVF as a shared experience to improve student learning and performance for articulation, and melodic accuracy. In contrast, when there was no individual or shared use of RTVF, there was no clear application of RTVF in lessons, as was observed in case study C.

Interview QDA findings supported video QDA findings of individual and shared RTVF use in piano learning, indicating that participant perspectives correlated with my perceptions gained from observations and technology-generated MIDI data on the application of RTVF in piano lessons. Interview QDA also suggested that RTVF was applied by some but not all participants, and perhaps in a very particular way, with a clear lesson focus, and when it did not distract the participants. Those observed using RTVF were the same as those who reported having made sense of it and then applying it to meet their individual needs, and those in a shared experience when the teacher made sense of RTVF and applied it with the student. This was illustrated in self-reports:

> S: So it helped me to see in real-time, right, how the outcome was (Student A, interview QDA after lesson 2)
>
> T: We see that sometimes that […] the legato we do is actually the pedal legato, […] instead of making a legato … by hand. (Teacher B, video QDA after lesson 1)
>
> S: I tried to see, I could not see all the time, you know, […] but I was getting … well… to interact with the graph that was being created. So you could see if the fingers were doing the accurate attack. (Student B, interview QDA after lesson 2)

In addition, MIDI QDA enriched the analyses, as it provided visual evidence and, in doing so, complemented the findings of both interview and video QDA. Specifically, MIDI QDA supported evidence that participants engaged with and used RTVF in those lessons which had a clear lesson focus, particularly regarding improvement of articulation and melodic accuracy.

At the same time, video QDA also revealed how other participants avoided engaging with RTVF. This avoidance reportedly occurred for several reasons, which were described in interview QDA. Reasons given included an apparent mismatch between visualization and sound of the performance, even when the lesson focused on playing instead of looking at the screen. Teacher C maintained that use of RTVF was avoided as they felt it could influence their opinion on student performance outcomes.

The effect of variability of practice (Schmidt, 1975) was investigated in studies in vocal (Welch, 1983, 1985b) and string (Pacey, 1993) learning and teaching. Although the schema of motor control proposed by Schmidt (1975) was not tested by experimental design in the current study, the findings of this exploratory action case study research concurs with findings from previous studies (Pacey, 1993; Welch, 1983, 1985b) where variability of practice and meaningful feedback are reported as being essential in order to achieve or promote learning. The technological environment of the current study may have allowed individuals the possibility of varying their practice alongside interpersonal feedback between participants. Thus, the application of technology in a piano studio brings variability of practice to HE piano learning and teaching alongside two types of interpersonal feedback, namely, verbal and non-verbal feedback between individuals, and additional visual and auditory feedback between individuals and technology.

Findings of this study show evidence of the potential of the application of RTVF in HE piano studios. These findings are also in line with those of previous studies on the usefulness and benefits of the application of RTVF in instrumental and vocal lessons (Brandmeyer, 2006; Sadakata et al., 2008; Welch, 1983, 1985b; Welch et al., 2005). In general, RTVF was shown to change teacher and student interaction. Specifically, RTVF use decreased the critical learning period that is commonly found in instrumental and vocal learning, which agrees with research in singing learning and RTVF (Welch, 1983; Welch et al., 2005). RTVF reduced the time between student performance first trial, teacher feedback both verbal and non-verbal, student performance second trial, and so on (Welch, 1983, 1985b; Welch et al., 2005). Similar findings of the current study support those of a previous study on technology uses in a singing studio (Welch et al., 2005), where differences were found in the individual pedagogical approaches used with technology across case studies. In contrast, teachers in this study had no experience of the technology system prior to their lessons. In addition, I operated the technology, whilst in a previous study 'teachers required only short induction periods to familiarise themselves with the technology' (Welch et al., 2005, p. 242).

Although findings of the current study concur with the idea that RTVF use can vary according to individual teaching approaches (Welch et al., 2005), what is unclear from previous studies is whether RTVF was used as an individual or shared experience between teacher and student pairs. This was possibly due to these previous studies using a year-long, thus long-term, technology application in instrumental and vocal studios. This long-term application of RTVF might have minimized differences in perceiving and using RTVF in singing studios. In contrast, the current research involved three case studies each of only two lessons held over five to ten days. This short-term period revealed individual differences between teachers and their students in perceiving and using RTVF. Differences in RTVF use may also be related to the lack of previous experience of teachers and students with this type of technology-mediated feedback.

Differences in RTVF use, in terms of individual or shared use, may also depend on a temporal synchronization between individuals (Novembre et al., 2014) that is similar to the synchronization when playing with partners in chamber music (Bishop & Goebl, 2015; Goebl & Palmer, 2009; Kawase, 2014). Thus, temporal synchronization might be needed between teacher and student in order to optimize their perception of the benefits of using RTVF with a clear lesson focus in a piano studio. Thus, findings of this study seem to complement those of previous studies regarding both the use of RTVF in a short period of time across two lessons and on individual and shared RTVF use for the improvement of particular musical performance parameters.

11.4.2 Additional post-hoc visual feedback

Findings from the video QDA suggest that post-hoc visual feedback occurred in two forms. The first form was in normal mode. In this form, a combination of post-hoc visual and auditory feedback was available when I played back recorded performance-related data. The second form of post-hoc visual feedback was in silent mode. In this form, I did not play the recording back, but switched the computer screen into silent mode. I then scrolled the computer screen up or down, and left or right, or left the screen frozen in front of the teacher and student, so that they could concentrate on the visualisation. MIDI QDA findings showed evidence of the application of post-hoc visual and auditory feedback through associations between technology and particular musical performance parameters, such as articulation, dynamic balance, rhythmic accuracy, and also pedalling, in order to improve student learning and performance.

Interview QDA findings supported those of the video QDA. Teachers and students reported that the visualization or graphic representation available on the computer screen could be taken as an alternative visual representation of music notation or musical performance. Participants also reported that additional visual feedback might offer a more realistic representation of piano performance through visualization of the keyboard and pedalling activity than conventional comparison of performance against the musical score. In other words, in conventional piano lessons, the performance is always compared to the immutable and fixed musical notation (Bautista et al., 2009; Hultberg, 2002). However, by applying additional post-hoc visual feedback, each piano performance attempt can be compared with its respective visual representations, which can change with each performance attempt.

Additional visual feedback of performance-related data seemed to accompany plasticity and variation in student performances. Nuances in the piano roll form visualization of performances were inferred to be closer to the nuances in the actual student performance. Additional visual feedback might also reduce the gap in conventional piano studios when reporting on performance and music notation, since the latter is an immutable and finished musical score, whilst student performance is likely to change over time with each attempt.

Interview QDA revealed preferences for different forms of additional visual feedback. The two participants in case study A demonstrated differing preferences: for dynamics, teacher A preferred to use colours, whilst student A preferred to use key velocity numbers. Individual differences are also evidenced in related literature (see Gaunt & Hallam, 2008, for an overview). Participant perspectives on the application of post-hoc visual feedback in lessons also related to improvement of articulation and dynamics in student performance, particularly in case studies A and B. However, although interview QDA revealed that participants in case study C could recognize and relate colour to dynamics, video QDA showed the pair did not seem to have used additional visual feedback. This disparity might be related to the fact that teacher C had doubted the extent to which the colour available to participants could reflect and correspond to the nuances of dynamics in piano performances. The level of participant engagement with additional visual feedback is discussed further below.

Discrepancies between video MIDI and interview QDA findings for additional visual feedback suggest that participants might have engaged with this feedback on different levels. Hence, the level of engagement with additional post-hoc visual feedback might determine whether participants were solely identifying MIDI parameters on the computer screen through the association between technology and music, in terms of musical score and musical structure, or whether they were using it to improve student learning and performance through the association between technology and performance (see Section 11.6). Given that there appears to be a difference in the way that individual participants engage with technology, the quality of interpersonal feedback between participants and technology might therefore be dependent on individual differences (see Gaunt & Hallam, 2008, for an overview).

The current study complements the existing body of research investigating the use of technology in HE piano learning (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010), in HE instrumental and vocal learning (Brandmeyer, 2006; Sadakata et al., 2008; Welch et al., 2005), and in vocal learning of children (Welch, 1983, 1985b). In the first instance, this study complements previous technology-assisted piano learning research which used technology (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010) by applying technology-mediated feedback alongside teacher and student feedback in a piano studio. In the current study, findings of the application of technology in piano studio-based learning were based on observation of lessons with teachers working alongside their students rather than based solely on perspectives of students on the use of technology to enhance learning (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010).

In the second instance, this study supports findings of previous RTVF instrumental and vocal learning research (Brandmeyer, 2006; Sadakata et al., 2008; Welch, 1983, 1985b; Welch et al., 2005) since it applied RTVF in HE piano studios. In addition, this study complements previous RTVF instrumental and vocal learning research (Brandmeyer, 2006; Sadakata et al., 2008; Welch, 1983, 1985b; Welch et al., 2005) since it investigates not only RTVF uses but also the use of post-hoc visual feedback in combination with additional auditory feedback.

Findings of this study are in line with the rationale and outcomes of a previous study (Welch et al., 2005). Using technology in a music studio enables the teacher and student to assess student performance outcomes in real-time whilst recording, and also to store and playback performance-related data for subsequent review and comparison. This study is extending findings in the literature by revealing how data available in real-time is also useful post-hoc for discussion and learning. The current study does this systematically and shows in great detail how the adopted technology system supports learning.

11.4.3 Additional post-hoc auditory feedback

Video QDA findings suggest that post-hoc auditory feedback was available to participants whenever I was playing back the recorded performance-related data to participants at two different speeds: at the original or slower (half-speed) tempo.

Post-hoc feedback use was related to the recorded performance-related data that was played back to participants who listened to the recording without playing. Performance-related data were derived from recordings of performances in real-time which were saved, stored, and could be accessed at any time through DAW software. The post-hoc visual and auditory feedback available across case studies varied in three aspects: (a) the performer participant who played the musical excerpt, that is, either the teacher, student or both; (b) the length of the musical excerpt in terms of the number of bars; and (c) the version of the recorded performance-related data when a musical excerpt was recorded more than once. Playback of recorded performance-related data available can be used by teachers and students in order to compare intended and actual performance outcomes, and to increase student conscious-awareness of their self-performances. Post-hoc feedback of recorded performance-related data in these three aspects brings several possibilities for comparison and discussion between teacher and student on their performance outcomes generated by different performers, musical excerpts, and recording versions.

Post-hoc auditory feedback, in combination with visual feedback, increased lesson focus since teacher and student were able to compare performance outcomes through a more attentive listening while not playing. The use of post-hoc auditory feedback through attentive listening was likely to have enhanced the listening experience of participants, particularly when combined with visual feedback of the keyboard and pedalling activity in their performances. Listening back to performance-related data brought to piano lessons a range of learning and teaching possibilities that could help participants optimize traditional piano learning and teaching approaches. The first instance related to comparisons between performance-related data by the teacher and student through consecutive listening. The second instance addressed specific musical excerpts of the recorded piece by clarifying lesson focus. The third instance encompassed comparisons between more than one version of recorded performance-related data of student by listening back. Versions of student performance outcomes before and after teacher feedback could be compared regarding one particular or more than one musical performance parameter which made performance goals well-defined.

Listening back to performance-related data supported autonomy in the student learning process since students could focus solely on listening, and self-assess their performance outcomes while they were not playing. However, video QDA findings for additional auditory feedback suggested multiple layers of musical performance parameters per bar. First, this occurrence of multiple layers can be related to overall ambiguous feedback for multiple lesson foci, such as dynamics, tempo, articulation, and phrasing. Second, it can also demonstrate potential relationships between musical performance parameters, for example tempo and rhythmic accuracy, and dynamics and phrasing. Third, multiple layers can also indicate prospective relationships between musical performance parameters and technology, for instance dynamics and the colours of MIDI notes, and rhythmic accuracy and the sizes of MIDI notes.

Interview QDA findings also supported video QDA findings. Participant perspectives supported observations that post-hoc auditory feedback enhanced piano learning. However, interview QDA was sometimes difficult to evaluate in terms of whether participant statements related solely to auditory feedback, or to a combination of auditory and visual feedback, since the post-hoc feedback encompassed both. Participant perspectives were positive regarding the application of post-hoc auditory feedback: this was viewed as beneficial to learning. Participants claimed there was a clearer lesson focus on the aspects of student performance requiring improvement when only listening. Attentive listening in combination with visual feedback was also helpful and more useful than playing and listening at the same time. Participants also thought that the immediacy of listening back to recorded performance-related data accelerated the learning process.

Findings of this current study suggest that when using post-hoc auditory feedback in an HE piano studio, technology can promote a transformative learning environment. There are at least two reasons for this. First, listening back to self-performances might enhance not only student awareness of their own performance, but also teacher awareness of the student performance. In addition, post-hoc auditory feedback of student performances offers a potentially effective pedagogical tool, replacing exemplar teacher modelling and exaggerated imitation of student playing. Second, post-hoc auditory feedback might enhance student perception of their own performance from another perspective, one which is perhaps closer to the perspective of a teacher. Once a student is not playing but listening back, more focused attention can be paid to performance outcomes.

Most studies of one-to-one instrumental and vocal learning have examined the predominant master-apprentice model of interaction between teachers and students and the traditional forms of teaching used in this pedagogical context (Hallam, 1998; Jørgensen, 2000). Findings of the current study align with more recent research which has reported the transformative potential that technology might bring if used with a clear purpose in instrumental and vocal learning and teaching (Creech & Gaunt, 2012). Examples of technology-aided learning include student perspectives of using technology for their own self-study (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010), and the application of technology in collaborative environments (Himonides, 2012; King, 2008; Savage, 2007). The current study also concurs with research in which additional visual and auditory feedback appeared to have contributed to a better understanding of student performances because students were able to compare intended and actual performance outcomes through post-hoc feedback, and thereby became more conscious of their own performances (Daniel, 2001; Riley, 2005; Zhukov, 2010). It can also be inferred that by using technology-mediated feedback, a student might develop ownership, autonomy and responsibility of their learning process (Carey & Grant, 2015a; Riley, 2005; Zhukov, 2010).

Findings of the current study also complement the findings of previous experimental studies which examined the roles of auditory, visual and proprioceptive feedback in solo piano learning, playing, and memorization (Banton, 1995; Finney & Palmer, 2003; Repp, 1999), and in piano duet performance synchronization (Bishop & Goebl, 2015; Kawase, 2014). Auditory feedback is reported as not assuming a main role in the playing and recall of accomplished piano performances by expert pianists (Finney & Palmer, 2003; Repp, 1999; Wöllner & Williamon, 2007), or in piano sight-reading (Banton, 1995). However, additional post-hoc auditory feedback may play a crucial role in improving specific aspects in a memorized piano performance due to auditory-motor associations in the brain (Bishop & Goebl, 2015; Brown & Palmer, 2012; Halwani et al., 2011; Moore et al., 2016). Research has also shown that additional post-hoc auditory feedback assumes an essential role in learning and memorizing a new piece (Finney & Palmer, 2003).

Overall, pedagogical and potential uses of technology-mediated feedback in HE piano studios varied across case studies. Additional feedback was used in real-time and post-hoc, at original or slower tempo, and in normal or silent modes, and varied according to performer, musical excerpt, and recorded performance-related data version. Additional visual and auditory feedback generated by the technology system augmented sensory feedback of participants as discussed below.

11.5 Augmented intrapersonal feedback through enhanced conscious-awareness

The application of technology-mediated feedback in HE piano studios generated additional visual and auditory feedback, which are not commonly available in conventional one-to-one piano learning and teaching environment. Additional visual and auditory feedback, set alongside teacher feedback, augmented intrapersonal feedback for student and teacher participants. Intrapersonal feedback encompasses not only sensory feedback, but also conscious-awareness, self-regulatory skills, metacognitive knowledge, and sense of self (see Chapter 3).

The use of technology-mediated feedback allowed teacher and student pairs to playback and listen to recorded performance-related data using DAW software. The listening back experience allowed participants to compare intended and actual performance outcomes. The application of this technology in HE piano studios provided the participants with opportunities to review student performance outcomes, and through this, to become more aware of their own performances and of improvements to be made.

The principal research source of conscious-awareness of performance outcome was interview QDA (see Chapter 10), complemented by the findings of video QDA for self-evaluation by students. In this study, the advantages of additional feedback were reported by participants who could clearly perceive what they were, or were not, doing in their performances. Students could realize what they were doing, and perhaps they could also understand better what their teachers really meant in their verbal feedback. Overall, teacher and student self-reports addressed the benefit of technology-mediated feedback in making students more conscious-aware of their performance outcomes by comparing the intended and actual performance outcomes.

In this current study, interview QDA showed improved conscious-awareness of performance outcomes in both teacher and student self-reports (see Chapter 10 for details). In video QDA, student self-evaluation showed greater conscious-awareness of their own performance outcomes when additional feedback was applied within lessons. In videoed lessons, self-evaluation also provided evidence that students were realizing aspects of their performances of which they had been unaware prior to using the technology-mediated feedback:

> S: It is better than it used to be, but still… It is like … I thought that … I didn't realize that there was so much [articulation of left hand]. (Student A, lesson 1)
>
> S: I have to improve that. […] This is what happens when you don't know the left hand well. (Student B, lesson 1)
>
> S: Before I thought that […] the leftover time was happening in the first [octave]. Then, after seeing that, I realized that it was [happening] in the last one [octave]. (Student C, lesson 1)

Findings of this study suggest that the level of conscious-awareness of performance outcome can be improved when additional auditory and visual feedback either in real-time or post-hoc, alongside teacher feedback, is available in piano lessons. Students can then realize more clearly what they are actually doing in their performances. These findings are in agreement with those of previous studies which state that conscious-awareness is related to multiple couplings of the visual-auditory-motor system (Acitores, 2011; Edelman, 2001; Lahav et al., 2007; Mathias et al., 2015). Other previous research has shown that listening back to self-performances without playing activated motor-auditory related regions in the brain (Brown & Palmer, 2012; Halwani et al., 2011; Lahav et al., 2007; Moore et al., 2016).

Thus, in the current study, conscious-awareness of performance outcomes was enhanced when students listened back attentively to their performance-related data with the addition of integrated auditory and visual feedback. Initially, students might have been unaware of particular performing actions when they were playing.

However, once technology generated additional post-hoc feedback, well-defined performance goals and lesson focus were underpinned, making students more aware of their performing actions. This finding tallies with a recent review of study findings that gaining conscious-awareness of performance action is a post-hoc phenomenon (Jeannerod, 2006).

The benefits of applying technology-mediated feedback in an HE piano studio include the improvement of student conscious-awareness of self-performances through students developing self-assessment skills, and self-critical reflective thinking (Carey & Grant, 2015a; Riley, 2005; Zhukov, 2010). Having additional feedback alongside teacher feedback in piano studios can support clearer lesson foci and well-defined performance goals, which can also improve self-regulatory skills (Nielsen, 2001), develop metacognitive knowledge (Hallam, 2001; Schraw & Dennison, 1994), and promote student self-assessment of their own performances via intrapersonal feedback systems (Hattie & Timperley, 2007; Welch, 1983; Welch et al., 2005).

The application of technology that integrates additional and meaningful visual and auditory feedback is a potential learning tool to help students become more independent and autonomous, and to change the traditional master-apprentice model of one-to-one tuition (Hallam, 1998; Jørgensen, 2000) into a more transformative pedagogical approach (Carey & Grant, 2015a; Creech & Gaunt, 2012). In general, the application of technology-mediated feedback augmented the intrapersonal feedback of participants in this study, particularly the students: it enhanced their conscious-awareness of their own performances, and subsequently enabled students to improve their learning (Acitores, 2011; Damasio, 2012). Student participants were able to self-evaluate their own performances while teachers acknowledged improvement of student conscious-awareness of their own performances.

Additional feedback generated by technology alongside teacher feedback informed participants about the difference between their intended and actual performance outcomes, reflecting previous research on feedback in education (Ramaprasad, 1983; Sadler, 1989). Additional visual and auditory feedback alongside teacher feedback enhanced self-regulatory skills and metacognitive knowledge of students, which also agrees with previous research (Hallam, 2001; Nielsen, 2001; Schraw & Dennison, 1994; Winne & Butler, 1994). In the current study, intrapersonal feedback of the student and teacher participants, in terms of sensory feedback, conscious-awareness, self-regulatory skills, and metacognitive knowledge, was augmented through the use of additional feedback generated by technology alongside teacher feedback.

Findings of this study complement those of previous studies which investigated roles of auditory, visual and proprioceptive feedback by removing or altering them in piano learning and playing (e.g. Banton, 1995; Finney, 1997; Furuya & Soechting, 2010; Kawase, 2014; Wöllner & Williamon, 2007). In the current study, there is evidence that additional visual and auditory feedback can enhance learning and performance, and augment not only sensory feedback, but also other aspects of intrapersonal feedback such as conscious-awareness, self-regulation skills, and metacognitive knowledge (Acitores, 2011; Damasio, 2000, 2012; Hallam, 2001; Nielsen, 2001; Schraw & Dennison, 1994).

11.6 Relationships between music, performance and technology parameters

Video, MIDI and interview data confirmed that technology can make more explicit the associations between music and its performance. While associations between music in terms of musical score and performance happen in a conventional piano studio, when mediated by additional visual feedback generated by technology, two other new associations arise: technology and music, and technology and performance.

Despite the availability of technology in this study, the characteristics of traditional piano lessons were observed nonetheless. These characteristics are mainly related to the use of the musical score regarding the musical structure, as in previous studies (Bautista et al., 2009; Hultberg, 2002). The higher frequency of feedback on music and performance parameters points to the strong associations made by teachers and students between musical notation and musical performance. This finding also concurs with the studies cited above, in relation to conventional instrumental and vocal lessons.

In conventional piano lessons, music notation is an incomplete source or guideline for interpretation where teachers and students commonly discuss by making associations between music, in terms of the musical score, and performance (Bautista et al., 2009; Hultberg, 2002). In contrast, in this study, when technology is applied in a piano studio setting, technology offers alternative means for discussion through associations between technology and music, and technology and performance. The higher frequency of teacher-student/student-teacher feedback on technology, notably MIDI parameters, in this study suggests that participants were able to more explicitly associate technology with either music, in terms of musical structure, or performance, for example, dynamics, timing, articulation, rhythmic and melodic accuracy, and pedalling.

MIDI QDA revealed that different pedagogical uses of technology-mediated feedback by participants were determined upon associations between parameters encountered in each case study. First, technology can be associated with music, or, more specifically, the musical structure of the piece, since it offers a graphic representation of musical notation, in terms of MIDI score, through additional visual feedback. Second, technology can be associated with performance, more specifically, dynamics, articulation and pedalling, since it represents a visualization of keyboard and pedalling activity from piano performances through additional visual feedback.

The association between technology and music seemed to be related to the engagement of participants at an initial and superficial level of conscious-awareness.

Student and teacher participants identified additional feedback with the musical score, but did not seem to apply technology in order to benefit their learning and teaching. For example, participants identified the colour differences in MIDI notation and associated it with different dynamics in musical score, but did not use this information to improve student learning and performance.

The association between technology and performance seemed related to the engagement of student and teacher participants at a second and deeper level of conscious-awareness, since they seemed to have applied technology in order to benefit their learning and teaching. For example, participants applied what they had perceived in terms of MIDI note colours, sizes, and spaces between notes in order to improve student performance with regard to dynamics, articulation, and rhythmic and melodic accuracy.

The interrelationships between the technology, music, and performance triad might support improvement student learning and performance objectively and clearly, and with a clear lesson focus as reported. Student learning and performance may be improved through detecting which performance parameters, for instance articulation, dynamics, and rhythmic and melodic accuracy, are more likely to be related to the technology-mediated data, for example, MIDI parameters in terms of MIDI notes colours, and sizes.

Findings of this study agree with those of a previous study on music education and technology use (Savage, 2007) where similar and different pedagogical approaches from the traditional approaches can be used in order to enhance learning. Associations between music and performance suggest traditional pedagogical approaches (Hallam, 1998; Jørgensen, 2000), whilst associations of music, performance and technology triad suggest transformative pedagogical approaches (Carey & Grant, 2015a; Creech & Gaunt, 2012).

11.7 Associative learning with auditory, visual and proprioceptive feedback

Findings of the current study suggest there might have been associative learning when additional technology-mediated feedback was available to learners through associations between three forms of sensory feedback, auditory, visual, and proprioceptive, in HE piano learning.

Findings from participant reports on the use of technology-mediated feedback in piano studios reveal the extent to which they were close to or far from their intended performance outcomes. Here, the application of technology-mediated feedback might promote a form of associative learning between visual, auditory, and proprioceptive feedback. This is in line with studies in motor control and learning which suggest that the use of technology provide associations between intrapersonal feedback and performance outcomes (Schmidt & Lee, 2011). Findings of the current study also agree with recent research in neuroscience and piano learning. Such studies investigated the role of the motor control system in the auditory perception and memory recognition of previously performed musical excerpts, which might promote associative learning (Brown & Palmer, 2012; Mathias et al., 2015). Similarly, Mathias et al. (2015, p. 2238) have argued that 'perception involves the comparison of incoming sensory information with information stored in memory'.

Supported by earlier research, the findings of the current study can be drawn on to infer that proprioceptive feedback can also be accessed through intrapersonal feedback, due to auditory-visual-motor associations (Brown & Palmer, 2012; Halwani et al., 2011; Mathias et al., 2015; Moore et al., 2016). It can be argued that proprioceptive feedback can also be augmented through additional auditory and visual feedback which is available to the student while listening back to and seeing the visual representation of their recorded performance-related data. For example, when the student is listening back to and viewing aspects of their performance-related data, they might perceive their actual performance as proprioceptive feedback, even though they are not actually playing the piece. Associations between visual and auditory feedback either in real-time or post-hoc might anticipate how an intended performance could look through additional visual feedback as a performance goal. Additional visual and auditory feedback might also enhance awareness of proprioceptive feedback of self-performances by associations of visual and auditory feedback.

Cognitive neuroscience research has demonstrated 'how auditory processing in humans can be modified by the presentation of visual stimuli' (Spence & Soto-Faraco, 2010, p. 271). Several studies were reviewed which presented evidence that 'the presentation of visual stimuli can have a variety of qualitatively different effects on a person's auditory (or perhaps more appropriately, multisensory) perception' (Spence & Soto-Faraco, 2010, p. 272). Additional visual stimuli, then, can either enhance or inhibit auditory perception. Visual stimuli can enhance auditory perception if visual and auditory feedback 'happen to be presented from the same location at about the same time' or 'if they happen to have a similar temporal structure' (Spence & Soto-Faraco, 2010, p. 290). However, visual stimuli can inhibit auditory perception when there is a dominance of vision over audition in some way and may even extinguish awareness of the sound (Spence & Soto-Faraco, 2010).

Similarly, the findings of this study suggest that additional visual feedback generated by the technology can enhance auditory feedback, particularly when the participant is visually driven or favours visual cues and uses visual feedback to augment or amplify auditory feedback. Visual learners can use additional visual feedback solely, and this can replace auditory feedback when the associations between visual and auditory feedback are understood by participants. This was observed when the pair of teacher A and student A used silent post-hoc feedback to examine dynamic balance between right and left hands through MIDI note colours and key velocity numbers on the computer screen (see Chapter 9 for details). There was no need to listen back to the recorded performance-related data as teacher and student A already knew what was going on with auditory feedback in terms of dynamic balance through additional visual feedback. This is a possible example of how additional visual feedback can inhibit or extinguish the combined use of additional auditory feedback in the current study. In contrast, additional visual feedback can be ignored when the participant is driven auditorily rather than visually, since in musical performance, and learning and teaching, individuals tend to focus solely on real-time auditory feedback.

Understanding of the different levels of engagement with additional feedback found in this study can be deepened by consideration of the seven levels of consciousness proposed by Rose (2006, pp. 360-361), who adopted a philosophical stance towards consciousness in the following systematic analysis:

> (1) Seeing red versus a different shade of red; (2) Seeing red versus green; (3) Seeing colour versus movement; (4) Seeing versus hearing; (5) Sensation versus perception, features versus objects; (6) Sensation/ perception versus cognition/thinking (versus emotional feeling, moving the body, etc.); (7) Awareness of self versus the world.

Findings of video, MIDI and interview QDA within and across case studies indicate that participants seemed to have engaged differently with additional visual feedback. For this reason, the current study suggests a model of two different levels of conscious-awareness with additional feedback. The first level of conscious-awareness in relation to performance outcome is when the teacher and student pair is able to establish a relationship between the music and technology. Examples of such relationships include identifying the music structure of the musical score in the MIDI notation and recognizing MIDI note colours as dynamics and MIDI note sizes as note durations. In this first level of conscious-awareness, however, there was no clear lesson focus or purpose for applying technology-mediated feedback to improve student performance.

The second level of conscious-awareness in relation to performance outcome is when the teacher and student pair upgrades the application of technology-mediated feedback with the clear purpose of improving student performance as a lesson focus.

Once the second level of conscious-awareness has been achieved, additional visual feedback can transform piano teaching and learning. Alternative associations between technology and performance can extend conventional pedagogical approaches where there is a tradition of associating performance and music, through analysis of the musical score. Traditional pedagogical approaches can be optimized through the use of technology in piano studios. Associations between performance and technology, through analysis of performance-related data which carries the nuances and plasticity of corresponding performances, can also promote transformative pedagogical approaches in piano studios.

In the current study, the enhancement of student learning can be effected through associations between intrapersonal feedback and performance outcomes (Schmidt & Lee, 2011) which include associative learning (Brown & Palmer, 2012; Mathias et al., 2015). Moreover, this study seemed to align with findings by Welch (1983, 1985a, 1985b) where three conditions were fundamental in promoting instrumental or vocal learning: KR, in terms of teacher feedback; additional feedback; and variability of practice. The first was verbal or non-verbal interpersonal feedback in the three areas of music, performance, and technology, acknowledgement of both teacher and student feedback. The second was additional auditory and visual feedback delivered by technology alongside interpersonal feedback. The third was variability of practice regarding how pairs of teachers and students used technology-mediated feedback pedagogically when supported by additional visual and auditory feedback, in real-time or post-hoc, in order to provide a clear lesson focus in piano lessons.

11.8 Perceived changes in the learning process and pedagogical approach

Findings of the current study through video, MIDI, and interview QDA suggest that changes in the learning process were observed by myself, as the researcher, and also perceived by teachers and their students. However, differences between teacher and student views on changes in pedagogical approaches were reported.

It can be argued that through the multi-method video QDA, including MIDI QDA, a change in learning and teaching might occur when technology-mediated feedback is applied in piano lessons. First, the nature of feedback in this study was verbal and non-verbal; both types were delivered by the teacher or student in reference to three main areas: music, performance and technology. These areas identify associations other than just that between music and performance which is customarily found in a traditional piano lesson. Also, when technology is available, the younger generation, being more accustomed to technological devices, can contribute to feedback in instrumental or vocal lessons. This is in addition to teacher feedback and allows a more collaborative environment to be established.

Second, the application of technology-mediated feedback generated additional visual and auditory feedback. Both of these are unavailable in traditional one-to-one piano lessons which are mostly based on real-time auditory feedback generated by the teacher and student when playing piano pieces. Third, the microstructure analysis of musical behaviour, namely, musical practice, and listening back, showed a change in piano pedagogy when additional feedback in the form of post-hoc auditory feedback was available at the original or slower tempo. MIDI QDA also indicated a change in pedagogical approach since additional visual feedback was available to participants either in real-time or post-hoc, and available separately or integrated with auditory feedback. Findings from MIDI QDA showed that additional visual feedback generated in the videoed lesson can enhance student learning and improve student performance, since additional visual feedback was seen to have supported clearer lesson foci and well-defined performance goals in a piano studio. These findings might be also related to the associative learning between visual, auditory and proprioceptive feedback accessed through the student intrapersonal feedback system. Findings of video QDA, including MIDI QDA, suggested a potential change in the learning and teaching processes in HE level piano tuition. However, a change in the learning process and teaching approach will not be observed if the use of real-time feedback is intermittent. This evidence is related to the predominant use of auditory feedback in real-time, something which is already available in conventional one-to-one piano tuition.

Interview QDA indicated overall convergence between teacher and student perspectives on change in the learning process, while suggesting divergence between teacher and student perspectives on change in pedagogical approach. According to the views of teachers and students, the application of technology-mediated feedback in an HE piano studio changed the learning process since it brought clearer lesson foci to the piano studio. According to student views, technology-mediated feedback was a new pedagogical tool with the potential to change learning and teaching processes. The teacher and student pair could either listen back to their recorded performance-related data in the form of additional auditory feedback, or view performance-related data through additional visual feedback immediately after playing the piano piece. As an additional pedagogical tool, technology-mediated feedback seemed to have accelerated not only the learning process, but also the teaching approach, since lesson foci were clearer.

Although students perceived a change in teaching approach when technology was used in a piano studio, this was not acknowledged by teachers. According to teachers, the application of technology-mediated feedback in HE piano studios can enhance, but not replace, student perceptions of their own performances. Additional visual or auditory feedback use was thought by teachers to increase student ownership, autonomy and responsibility for the learning process while making performance goals clearer. No change in teaching approaches was acknowledged by the teachers themselves as the pedagogy was perceived as being quite similar to that of traditional one-to-one piano lessons. It is possible that the teachers did not notice a change in their pedagogical approaches as they were not manipulating the technology themselves. However, students did perceive changes in teaching approach even though I, as facilitator, operated the technology within lessons. Nonetheless, teachers did perceive learning and teaching process to be accelerated compared with traditional one-to-one piano lessons.

Video QDA, including MIDI QDA, showed evidence of change in learning process and teaching approaches as technology was applied in a piano studio. Interview QDA demonstrated similarities between teacher and student perceptions regarding changes in the learning process, but differences regarding changes in pedagogical approaches, in agreement with reported studies (Savage, 2007). At the same time, all participants noticed a quicker pace in the learning process; this was perhaps because lesson foci were clearer and performance goals well-defined. These findings concur with previous studies which reported on the use of technology as a transformative pedagogical tool in instrumental and vocal learning (Creech & Gaunt, 2012; Gaunt, 2007, 2009), and for the enhancement of the student learning process or more effective teaching approaches (Carey & Grant, 2015a).

The match between teacher and student perspectives on learning processes and teaching approaches echoes previous studies which investigated the match between 'preferred learning styles and corresponding teaching styles' (Felder & Silverman, 1988, p. 675; Franzoni & Assar, 2008). Although these studies initially made reference to visual/auditory learning and teaching styles, an updated version of the same paper referred to visual/verbal dimensions (Felder & Henriques, 1995), and did not refer to non-verbal or auditory feedback. Findings of the current study converge and complement the former, but diverge from the later perspective of these previous studies for the match between learning and teaching styles.

This current study focuses on music instrument learning and teaching and the use of technology; it involves not only verbal and non-verbal teacher and student feedback on music, performance, and technology, but also the additional visual and auditory feedback generated by the use of technology. This study counterpoints previous studies on learning and teaching styles in general (Felder & Silverman, 1988; Franzoni & Assar, 2008), and adds the perspective of four main types of learning and teaching styles which can be discussed in a piano learning environment when technology-mediated feedback is applied: verbal and non-verbal, and visual and auditory.

For example, in case studies A and B participants seemed to use either verbal or non-verbal feedback on technology parameters much more than in case study C. This difference might be related to learning or teaching style preferences for the use of technology by case study A and B participants, thus demonstrating the incorporation of technology by teachers and students into their verbal and non-verbal behaviours. Similarly, silent post-hoc visual feedback seemed to be the preferred learning and teaching styles in case study A, while RTVF seemed to be the characteristic learning style of case study A, and learning and teaching styles in case study B. Post-hoc visual and auditory feedback seemed to be the favoured learning and teaching styles across all three case studies. Table 11.1 presents an approximate view on the match between learning and teaching styles in each case study when technology-mediated feedback was applied in a piano studio.

Table 11.1 Perceived matches between learning and teaching styles across case studies

Types of feedback			Learning styles			Teaching styles		
			Case studies			Case studies		
			A	B	C	A	B	C
Interpersonal between individuals	Verbal	Music	√			√	√	√
		Performance				√	√	√
		Technology	√	√		√	√	√
	Non-verbal	Music	√	√		√	√	√
		Performance	√		√	√	√	√
		Technology	√	√		√	√	
Interpersonal between individuals and technology	Additional visual and auditory feedback	Real-time visual feedback (RTVF)	√	√			√	
		Silent post-hoc visual feedback	√			√		
		Post-hoc auditory and visual feedback (original tempo)	√	√	√	√	√	√
		Post-hoc auditory and visual feedback (slower tempo)			√			√

Table 11.1 is derived from video QDA, including MIDI QDA; it shows that teaching styles uniformly incorporate verbal feedback, but not non-verbal feedback on technology alongside music and performance, while learning styles differ according to the learner. Teaching and learning styles uniformly incorporated post-hoc auditory and visual feedback, but differed in the uses of RTVF, silent and slower post-hoc visual feedback.

Participants who engaged with technology in the form of additional visual feedback in this study might be considered as potential visual learners, while those who engaged with technology mainly in the form of additional auditory feedback might be considered as potential auditory learners. Visual learners seemed to have related technology to music and performance. However, even visual learners can demonstrate differences, due to their different levels of conscious-awareness: the first level allows for identification and the second level for the application of technology parameters (see section 11.7). Auditory learners seemed to have related music to performance as is commonly found in traditional individual piano tuition. However, piano students are also proprioceptive, including tactile and kinaesthetic, learners by nature since piano learning involves doing, in the sense that learners perform, practice, and play in their piano lessons.

This study agrees with previous research findings (Felder & Silverman, 1988, p. 680) since mismatches between learning and teaching styles 'may lead to poor student performance'. As with previous research findings (Franzoni & Assar, 2008), in this study not only did the compatibility between learning and teaching styles need to be taken into account with regard to improving student performances, but also the appropriateness of the specific characteristics of the technology used in piano lessons for both teacher and student.

In summary, additional feedback might play a significant role in the learning of visual and auditory learners in instrumental lessons due to the integration of additional visual and auditory feedback in this study. Once a teacher is aware of the potential learning styles of their student, they can adapt or match their teaching styles still further. Teachers can also adopt other pedagogical approaches, in order to achieve a match between learning and teaching styles and to promote and support effective feedback in a piano studio.

In this study, technology was found to be potentially beneficial for piano learning and teaching since it seemed to offer a tool for transformative pedagogy. Several types of additional feedback generated by technology were available for the student and teacher, who worked alongside each other on the improvement of student performance of a memorized movement from a classical sonata of their current repertoire. Additional auditory and visual feedback, either real-time or post-hoc, provided a significant amount of detailed information about the performance.

However, it is important to stress that additional visual-auditory feedback cannot be seen as a substitute for teacher feedback. Rather, the usefulness of the application of technology-mediated feedback lies in its being integrated with teacher feedback: this seemed to have supported student learning and performance more fully.

These findings concur with those of previous studies on motor control and learning (Kernodle & Carlton, 1992; Schmidt & Lee, 2011; Wallace & Hagler, 1979) since technology can enhance learner performances when used with clear and well-defined performance goals in combination with feedback from teachers. Findings of this study also agrees with those of previous studies on the technology use in singing studio (Welch, 1983, 1985b; Welch et al., 2005), music studios and music classroom learning (Himonides, 2012; King, 2008; Savage, 2007), and piano learning (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Zhukov, 2010).

Findings of this study thus suggest that there is a use for technology-mediated feedback alongside teacher feedback, and that this can optimize more traditional pedagogical approaches in HE piano learning and teaching. Although I facilitated the application of this technology system alongside teacher and student pairs in their piano studio settings, the actual application of the findings of this study on a piano studio depends on the use of this technology system by teacher and student pairs themselves. Previous studies demonstrated that Continuing Professional Development (CPD) programmes benefit the development of pedagogical approaches in choral conducting (Durrant & Varvarigou, 2008), and in music education (Varvarigou, Creech & Hallam, 2012). Thus, there is a need for institutions to offer CPD programmes for teachers (and their students) in order to improve their skills in technology use in the pedagogical setting, and to demonstrate how technology can be used as a pedagogical tool in an HE piano studio without a facilitator.

11.9 Emotional responses to technology-mediated feedback uses

Emotional responses towards the use of technology-mediated feedback in HE piano studios seemed to be a point of interest, since these were part of the experience of teachers and student with technology, albeit being a more minor finding. These responses were observed and reported in video and interview QDA, respectively. Findings suggest that participants, particularly students, might show negative, positive or ambiguous emotional responses or anxiety when listening back to, and critically self-assessing, their own recorded performances in lessons.

Video QDA revealed that some disruption was caused to teachers and students by the application of RTVF while the student was performing. For teachers and students, the disruption was part of their adaptation to the technology; it was needed so they could then benefit from what technology-mediated feedback was bringing to the piano lesson.

Teacher and student pairs commonly expressed negative emotional responses to the technology. It was thought that the technology disturbed the student by causing memory lapses, especially when the student was using it in real-time:

> T: I am a bit lost here… I think I am nervous […] Thankfully I am not playing […] It is a different situation in which we can become lost. (Teacher A, video QDA, lesson 1)
>
> S: I was also nervous with the presence of all of these pieces of equipment. I started to play, then I saw these little blocks, I got lost. (Student A, video QDA, lesson1)
>
> T: But sometimes this [technology in real-time], in some moments it distracted you [Student B] a bit […] I have noticed […] but it’s good. […] Then, suddenly in a more regular use, […] you […] get used to it. (Teacher B, video QDA, lesson 2)

Positive emotional responses were also observed in the video QDA when participants acknowledged and commented on the advantages and benefits of using technology-mediated feedback. One example was to improve the piano performance by making lesson focus on particular musical performance parameters clearer:

> S: Ah [that was] one thing that I had noticed with a bit of attention, but it is clearer here, alright? […] Yeah, you can see well this as well. (Student A, video QDA, lesson 1)

> T: It's nice […] for us to do this […] deep cleaning, […] this prophylaxis as well, right. […] It is funny that we can see […] Very good. (Teacher B, video QDA teacher B, lesson 1)

Ambiguous emotional responses were noted when participants seemed to be upset by the additional feedback on their performances, even if they recognized the benefit of using the feedback and appreciated being able to improve their playing. Ambiguous emotional responses were also observed when, for instance, a teacher used an apparently ironic tone, commenting that the pair should acquire the technology for use in their lessons. A contradictory opinion was shown by one teacher who expressed curiosity before applying the technology, but then complained about the additional feedback that was provided immediately afterwards. Ambiguous emotional responses are illustrated as follows:

> T: Now we are going to buy this sort of thing [this tool], […] in order to do once […] one class per month like this, alright, [name of Student B]? (Teacher B video QDA, lesson 2)

> T: Well …let's deal with this thing a bit because I think the… the program can help you a lot, […] which is the rhythmic precision, right. […] It is very annoying to put it at the right tempo. […] That's it, look —so boring this […] Oh, people, it makes anyone angry, right? (Teacher C, video QDA, lesson 2)

> S: This is the machine which reveals the truth. (Student B, video QDA Student B, lesson 2)

Interview QDA also demonstrated that some students saw the interviews as an opportunity to acknowledge the anxiety they might have felt in taking part in the research project. It was not only the presence of a researcher watching their usual one-to-one piano lessons but also all the technological apparatus involved in the research project that could have created anxiety:

> S: Well, I think it is normal that the person feels maybe a little inhibited, maybe … maybe a little nervousness about all this apparatus, you know. (Student A, interview after lesson 1)
>
> S: There is … a stranger watching my piano lesson, you know. […] It did not bother me, so I was not embarrassed or anything. But there is an audience, right! (Student B, interview after lesson 1)

Acknowledgment of anxiety by students might also be related to the extent to which they engaged with the technology in the lessons. Negative emotional responses were reported in case studies A and B where participants engaged with additional visual feedback, while the lack of anxiety in case study C was linked to a sense of less engagement with the provided technology.

Interview QDA also revealed emotional responses were mostly reported regarding lesson 1 rather than lesson 2, due to an unfamiliarity of participants with the technology, graphic visualizations, and also as to how the lesson would be conducted or might develop. Video QDA demonstrated that most of the participants seemed to be a little apprehensive about the new situation in lesson 1 whilst they appeared to feel more confident and to have a clearer idea about what to expect from the use of technology in lesson 2. In addition, the participants appeared to be better adjusted to the technology-mediated feedback, and had learnt how to deal with the technology by understanding it.

Findings of the current study agree with those of previous research which investigated the use of RTVF in singing studios (Howard et al., 2004; Welch et al., 2005). One report in this previous study observed ‘initial misgivings about whether it was possible to focus on a student’s singing whilst using the technology’ (Welch et al., 2005, p. 241). In another report of the same study ‘students [found] that watching the display [was] rather too distracting when they [were] concentrating on performing a piece' (Howard et al., 2004, p. 143).

This finding also agrees with previous research which investigated musical performance anxiety before, during, and after musical performances (Papageorgi, Hallam, & Welch, 2007), and stress management in musical performances when playing in chamber music groups (Facchini, Harper, La, & Ricca, 2013). Although participants exhibited emotional responses towards the use of technology in their lessons, its use revealed a clear lesson focus where teachers and their students could assess their own performances through additional feedback in their lessons.

11.10 Summary

In this chapter, the findings of video, MIDI, and interviews QDA were discussed in order to examine whether they complement, contrast, or support each other. Literature was revisited in order to evaluate how the findings of the current study can contribute to knowledge. Video, MIDI and interviews QDA findings suggest that the use of technology-mediated feedback, specifically additional visual-auditory feedback, seemed to enhance the interpersonal and intrapersonal feedback of teachers and especially students in this dyad context.

Interpersonal feedback between teacher and student was verbal and non-verbal in each of the three main areas: music, performance, and technology. This finding agrees with those of previous studies where technology can either support or extend traditional pedagogical approaches (Savage, 2007), and also bring a more collaborative environment in lessons (King, 2008). Types of verbal and non-verbal feedback were provided not only by teachers, but also by students through self-assessment of their performances in lessons. This student use of interpersonal feedback might be related to an increase in their ownership, autonomy and responsibility for the learning process (Carey & Grant, 2015a; Riley, 2005; Zhukov, 2010).

Perspectives on learning process change were perceived across case studies: the use of technology-mediated feedback seemed to make lesson foci clearer and promote accelerated learning through the listening experience and the immediacy of listening back after playing. Otherwise, perspectives on change in pedagogical approaches diverged across participants, since teachers did not acknowledge much change in their teaching styles from conventional one-to-one piano tuition. In contrast, students reported perceived changes in pedagogical approaches when technology was used in lessons. Perhaps better matches between teaching and learning styles (Felder & Silverman, 1988; Franzoni & Assar, 2008) might promote more effective feedback on student learning and improvement of performance. Overall, participants and I perceived that additional feedback generated by technology has the potential to transform pedagogical approaches for the enhancement of learning and performance in HE piano studios learning (Carey & Grant, 2015a; Creech & Gaunt, 2012; Gaunt, 2007, 2009).

Pedagogical uses of technology-mediated feedback were discussed through video, MIDI, and interview QDA. Additional visual and auditory feedback was available in real-time or post-hoc, normal or silent mode, and at the original or slower tempo. Different pedagogical approaches were used to make lesson foci clearer in order to improve student learning and performance. Characteristic forms of pedagogical uses differed across the three case studies, in terms of RTVF, silent post-hoc visual feedback, and slower post-hoc auditory and visual feedback. This finding agrees with a previous study where individual teaching strategies differs when using RTVF in singing studio (Welch et al., 2005). However, the use of post-hoc visual and auditory feedback was observed and unanimously reported across case studies to be a potentially helpful and enriching pedagogical approach.

Findings of this study support those of previous research on RTVF use (Welch, 1983, 1985b; Welch et al., 2005) where RTVF use can be seen to decrease the critical period of learning between student performance and teacher feedback. Additional feedback also brings numerous possibilities since it varies in three aspects: the performer, the selected musical excerpt, and the version of the recorded performance-related data. This finding also extends those of previous research on RTVF use (Welch, 1983, 1985b; Welch et al., 2005); this suggests that post-hoc visual and auditory feedback can be used in HE piano studios to enhance student learning and performance.

Since additional feedback contains aspects related to student performance, the student can associate visual, auditory, and proprioceptive feedback through their intrapersonal feedback system in order to improve their learning, and performance. Associative learning and multiple couplings of the auditory-visual-proprioceptive system are widely held to enhance conscious awareness (Acitores, 2011; Edelman, 2001; Lahav et al., 2007; Mathias et al., 2015). However, the use of a new technological tool, including a digital piano, might affect emotional responses from teachers and students.

Additional visual and auditory feedback generated by technology augmented intrapersonal feedback of teacher and student participants not only in terms of sensory feedback, but also their conscious-awareness of performance outcomes. When comparing intended and actual performance outcomes, students become more conscious of their own performance outcomes (Acitores, 2011; Damasio, 2012; Edelman, 2001) since additional visual-auditory feedback, especially post-hoc, can enhance conscious-awareness (Jeannerod, 2006). Students can also become more conscious of their performance outcomes when they are able to self-assess and self-monitor, as they are not playing and undertaking self-assessment at the same time.

The use of technology seemed not only to favour student self-assessment but also to enable student development of self-regulatory skills, thereby optimizing student learning and performance through interpersonal and intrapersonal feedback systems since lesson foci appeared to be clearer when participants used additional visual-auditory feedback. This clearer lesson foci chimes with evidence that advanced level instrumental and vocal students have the potential to develop their self-regulatory skills (Nielsen, 2001) and then decrease differences between their intended and actual performance outcomes (Latham & Locke, 1979), since self-regulatory skills are enhanced by clear lesson foci or goal setting, self-monitoring, and self-reflection (Zimmerman, 1998). Combined, these potential outcomes of additional visual-auditory feedback can enhance student learning experience. In Chapter 12, the conclusion of this study is presented.

12 Conclusion

12.1 Research questions

This exploratory study addresses three research questions concerning the pedagogical use of technology-mediated feedback in HE piano studios. The methodology adopted involved multiple-source data collection and production, multi-method data processing and analysis, and an exploratory action case study approach. The application of technology-mediated feedback by myself, as the researcher with a facilitator role, was investigated in HE piano studios with three student and teacher pairs who worked on memorized classical sonatas of their current repertoire during two lessons.

The first aim of the study was to investigate the nature of feedback when technology-mediated feedback is applied in HE piano learning and teaching. The first research question, given below, was answered based on findings of the video and MIDI QDA.

1. What is the nature of feedback in higher education piano learning and teaching when technology-mediated feedback is applied?

In respect of the first research question, the nature of feedback in HE piano learning and teaching when technology-mediated feedback is applied is both intrapersonal and interpersonal. It can be argued that intrapersonal feedback in piano learning and playing involves not only sensory feedback, in terms of visual, auditory and proprioceptive feedback, but also conscious-awareness, self-regulatory skills, metacognitive knowledge, and sense of self (see Chapter 3). In addition, the nature of feedback in HE piano learning and teaching, when technology-mediated feedback is applied, is interpersonal in two forms: between the participants themselves; and between the participants and technology (see Chapter 4).

The nature of interpersonal feedback between individuals in this current study is verbal and non-verbal, occurring between teacher and student participants. Interpersonal feedback between participants was verbal which involved providing information, giving directions, and asking questions, as well as non-verbal as demonstrated by body and head movements, pointing, gesturing, and touching. Types of verbal and non-verbal interpersonal feedback were delivered by either teacher or student, and linked to three parameters, namely, music, performance, and technology. Music parameters involved aspects of the musical structure of the chosen piece. Performance parameters involved aspects of playing such as dynamics, articulation, and phrasing. Technology parameters involved aspects of MIDI parameters such as MIDI note colours and sizes. Although teacher feedback is more predominant in lessons, when technology is applied in a piano studio, student feedback is more likely to occur, especially in regard to the technology.

The nature of interpersonal feedback between teacher and student participants and technology in this study is in terms of sensory feedback through additional visual and auditory feedback. This additional feedback was generated by the technology system used and was made available to participants. Although additional visual and auditory feedback could be delivered simultaneously, the three teacher and student pairs engaged with technology in different ways favouring either visual or auditory feedback according to their individual differences, and perhaps their own preferences.

The introduction of technology in a piano studio promotes additional open and closed feedback loops in the interpersonal feedback between individuals and technology. Interpersonal feedback can be open, as demonstrated by verbal and non-verbal feedback between student and teacher, and also closed as exemplified by feedback between individuals and technology, specifically, additional visual and auditory feedback. This additional closed loop occurs in order to make students more conscious of their own performance outcomes by comparing intended and actual performance outcomes with a clear and well-defined lesson focus or performance goals. Perhaps the additional sensorial feedback, which technology promotes, augments student and teacher intrapersonal feedback.

If the teacher and student pair is aware of additional visual feedback and make sense of it, verbal or non-verbal feedback is generated by either the teacher or student concerning technology, for example, MIDI parameters, MIDI recording version, and digital piano. Thus, it is suggested that teacher and student might engage with technology through visual feedback since their interpersonal feedback relates to technology. However, if the teacher and student pair does not make sense of additional visual feedback, no interpersonal feedback concerning technology seems to be generated by either the teacher or student. It is suggested that teacher and student might purely engage with technology through auditory feedback since their interpersonal feedback relates to music and performance as found in traditional piano lessons.

In this study, interpersonal feedback was similar to and different from conventional one-to-one piano lessons. Feedback was similar in regard to music and performance parameters which were worked on in piano lessons. Feedback was different in regard to technology parameters, and for additional forms of sensory feedback, in terms of visual and auditory feedback. Although intrapersonal feedback was not measured in this study, it can be inferred that additional visual and auditory feedback augmented the intrapersonal feedback of student and teacher participants in their piano lessons.

Two models illustrate the nature of feedback: (1) in a one-to-one HE traditional piano studio setting; and (2) in a technology-mediated feedback HE piano studio setting. In both settings, the context is the improvement of student learning and performance of a chosen repertoire by targeting performance goals. The first model (Figure 12.1) illustrates a model of feedback patterns in a conventional piano studio when teacher and student work on a selected piano piece. The individual student and teacher intrapersonal feedback systems are represented respectively by rope drawing images on the top and bottom of the model. Interpersonal feedback between individuals encompassed mainly student performance, teacher feedback and teacher performance, including modelling or imitating student performance. There is a cyclical process involving student performance and teacher feedback including teacher performance which tends to be repetitive with slight variations of feedback patterns. Student performance, in terms of a whole piece or excerpts of a piece, is presented to the teacher. Thus, teacher feedback (verbal and non-verbal), specifically on music and performance parameters, is provided in order to improve student performance and enhance student learning. This cycle can be repeated over time in various forms as depicted in Figure 12.1. Figure 12.1 shows patterns of feedback reasonably equally spaced even though timing of feedback patterns can vary and are context specific.

The second model (Figure 12.2) illustrates a model of feedback patterns when technology-mediated feedback is applied to an HE piano studio alongside teacher and student. The main aim in the piano lesson was to improve student learning and performance of a chosen memorized piano work from their current repertoire for particular musical performance parameters whilst exploring the technology-mediated feedback. This model shows some of the same information as Figure 12.1 in terms of individual intrapersonal feedback and interpersonal feedback between student and teacher. In comparison with Figure 12.1, Figure 12.2 adds the following information: (1) a waveform drawing image which represents additional feedback types generated by the technology system that are available in piano lessons, either in real-time or post-hoc; (2) post-hoc student feedback (intra- or inter-personal), which is more likely to occur when technology is applied in piano studios alongside teachers; and (3) student recorded performance-related data which is listened to and looked at on the computer screen post-hoc. Thus, the second model suggests that additional feedback patterns are available alongside those feedback patterns which are usually available to the teacher and student pairs in one-to-one conventional piano lessons. The application of technology-mediated feedback includes additional visual and auditory feedback. Additional visual feedback presents the visualization of performances in piano roll form in black and grey shades (B&W), when the performance-related data are recorded; and in B&W or coloured forms, when the recorded data is played back. Additional auditory feedback encompasses the listening back to recorded data exactly as it was played by participants. Interpersonal feedback in this model encompasses not only verbal and non-verbal feedback, but also additional auditory and visual feedback which is generated by the technology system used.

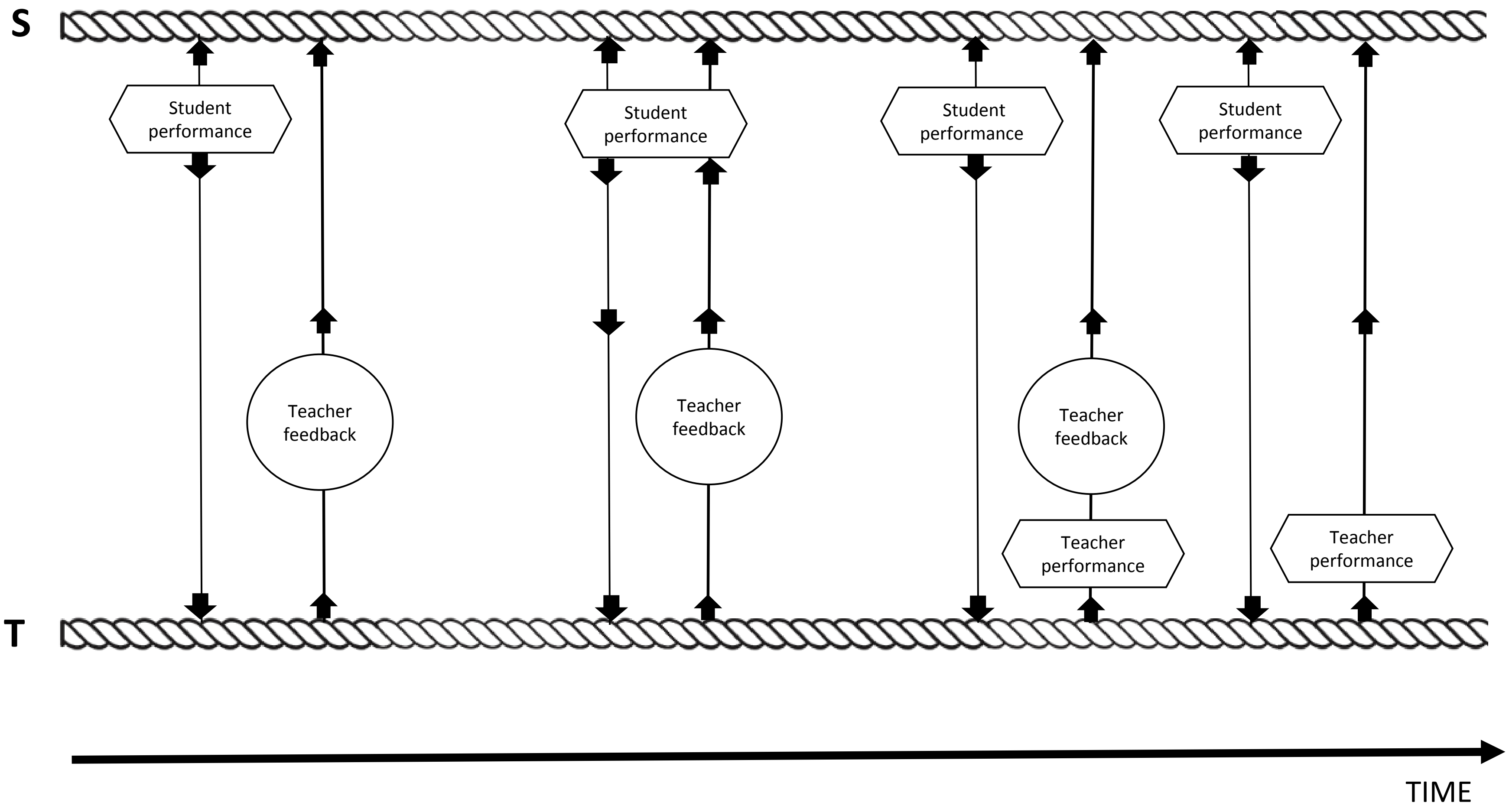


Figure 12.1 Model of feedback patterns in conventional one-to-one HE piano learning and teaching

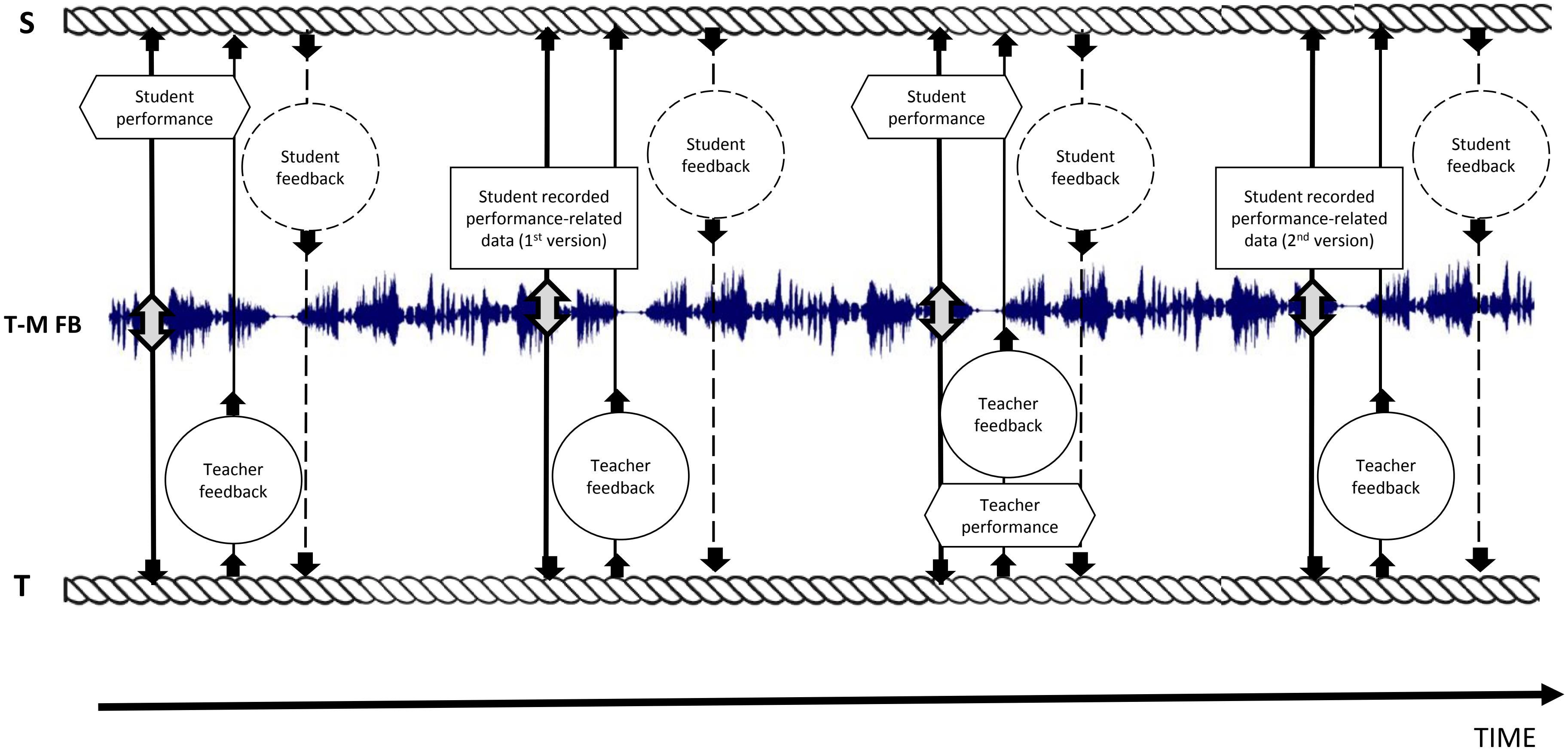


Figure 12.2 Model of feedback patterns in an HE piano studio with the application of technology-mediated feedback

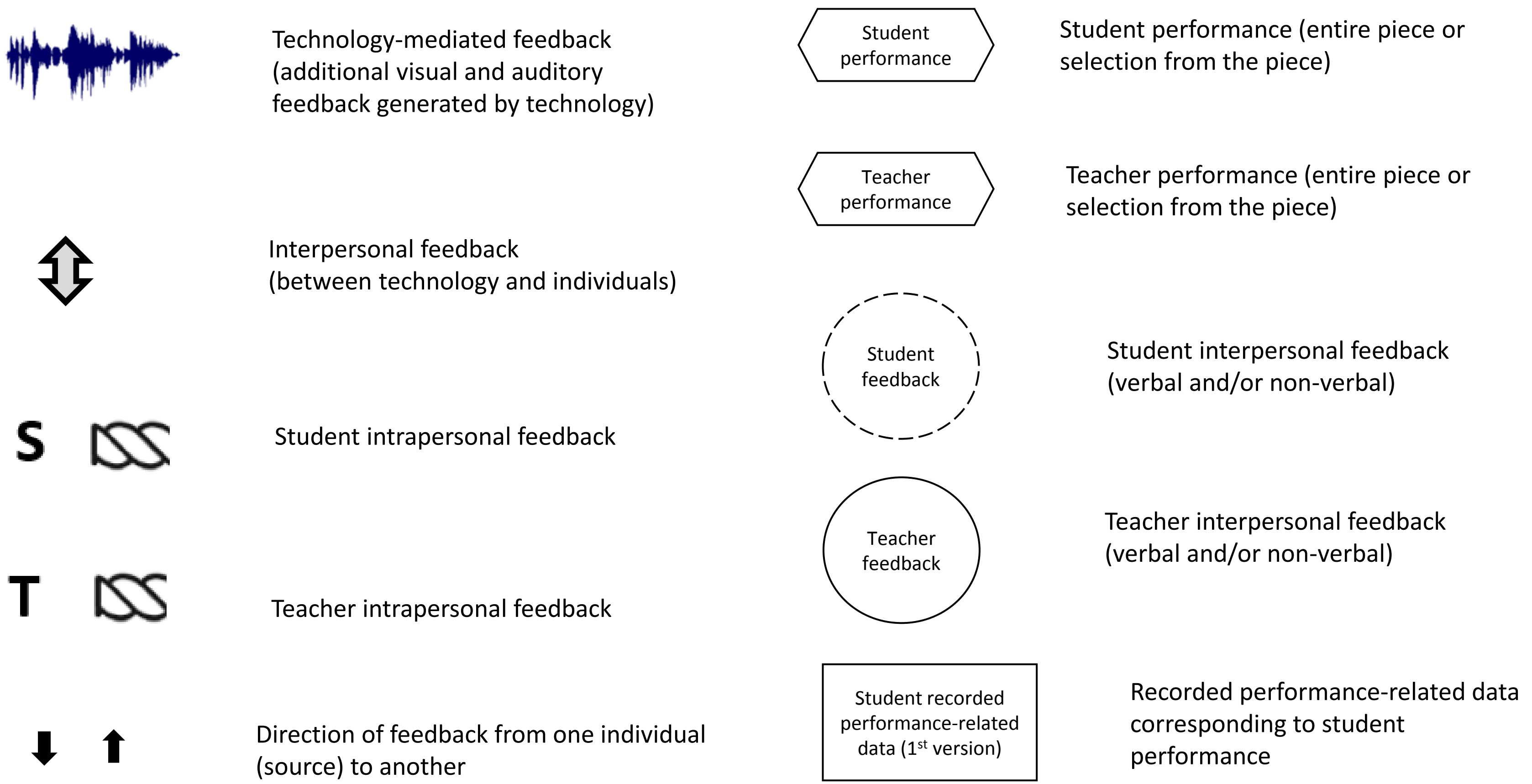


Figure 12.3 Legend for two models of feedback patterns

Key: Figure 12.3 shows the legend used in conventional HE one-to-one piano learning and teaching, and in an HE piano studio with the application of technology-mediated feedback

The second aim of the current study was to examine the pedagogical and potential uses of technology-mediated feedback in HE piano learning and teaching. The second research question was answered based on findings of the video and MIDI QDA.

2. How is technology-mediated feedback applied in higher education piano learning and teaching?

In the current study, and in relation to the second research question regarding how technology-mediated feedback is applied in HE piano learning and teaching, the pedagogical use of technology-mediated feedback was evidenced in four main forms: one using real-time and three using post-hoc feedback. The first form was RTVF. In this form, additional visual feedback in a black and grey shade was available to teacher and student participants whenever they were playing the chosen piano piece while I was recording the performance-related data on DAW software. The second form was post-hoc visual and auditory feedback in the original tempo. In this form, additional visual and auditory feedback was available to teacher and student participants whenever they were seeing and listening to recorded performance-related data while I was playing it back. Additional visual feedback in post-hoc was available by using either the black and grey shade or coloured screen in the DAW software interface although the colour option dominated. Additional auditory feedback in post-hoc was made available by playing back the recorded performance-related data exactly as participants had played the piece(s). The third form was post-hoc visual and auditory feedback at slower tempo, such as half of the original tempo. In this form, additional auditory feedback was available to participants whenever I was playing back the recorded data at half tempo. The fourth form was silent post-hoc feedback. In this form, additional visual feedback in post-hoc was available whenever I was scrolling the computer screen up and down, left to right, or when I just left a frozen computer screen in front of the student and teacher in a silent mode.

Individual pedagogical approaches were observed by myself and reported by participants across case studies so as to improve student learning and performance for particular musical performance parameters. RTVF was used as an individual experience, without partner awareness, or as a shared experience, with partner awareness. Post-hoc visual and auditory feedback was used as a shared experience, between teacher and student participants, in all of the three case studies.

The most commonly observed type of technology-mediated feedback across the three case studies was post-hoc visual and auditory feedback in the original tempo. However, the participants in each case study seemed to have used technology in their own particular way. For example, silent post-hoc visual feedback was used in case study A, RTVF in case study B, and post-hoc visual and auditory feedback at a slower tempo in case study C. These use preferences might be related to either a particular way of learning and teaching within each case study or the way in which I supported each student and teacher pair. The application of technology-mediated feedback seemed to occur when the teacher wanted to make a student aware of an aspect of their performance whilst working on the improvement of student performance for particular musical performance parameters. Thus, although the technology-mediated feedback was available to participants throughout most of each lesson, its effective application seemed to occur when the teacher-student pair had a well-defined performance goal and clear lesson focus that aimed to improve student learning and performance.

The technology system applied in this study allowed myself, as the researcher, to record, save, store, and playback performance-related data to participants by reproducing participant performances in exactly the same detail as the pieces had been played. Performance-related data varied in three aspects: performer, such as teachers and students; length of musical excerpts, in terms of the musical sections of bar groups; and versions of the recorded data. A wide range of possibilities regarding the playback of performance-related data is offered to teacher and student participants when using the technology system so that they can make comparisons between different versions of performance outcomes. Post-hoc feedback, in terms of playing back and listening to recorded performance-related data, is a potential learning tool. Post-hoc feedback contributed to a greater self-reflection by students on their own learning and performance once lesson foci had been made clearer in piano studios, and alongside teacher feedback. The use of playback increases student conscious-awareness of their performance outcomes; it also develops their self-regulatory skills and metacognition knowledge as it allows students to compare intended and actual performance outcomes.

The potential pedagogical uses of the technology-mediated feedback for improving student learning and performance were evident since additional feedback was available to participants for use at any time in their lessons. In addition to the reported uses of technology-mediated feedback, there may have been other possibilities which did not seem to have been exploited, but which could have been used successfully in this study. One example includes the use of real-time over post-hoc feedback, by recording over the playback, for improving dynamic balance. Another example includes the use of post-hoc feedback use for improving pedalling. Both examples were attempted in case study A. In this sense, the application of technology-mediated feedback in a piano studio brings with it the potential for a multiplicity of possible uses and benefits. The extent to which teacher and student pairs engaged with either visual or auditory technology is unclear since additional feedback integrated both visual and auditory feedback. Perhaps the difference between visual and auditory interactions can be compared to verbal and non-verbal feedback regarding music, performance, and technology. Since verbal and non-verbal feedback on technology involved the aspects related to MIDI parameters which were available to participants visually, it can be inferred that the greater the types of feedback on technology the greater the engagement with technology for visual feedback. Alternatively, when types of verbal and non-verbal feedback were delivered mostly with regard to music and performance, it is suggested that participants engaged with the technology mostly through auditory rather than visual feedback. When the teacher and student pair engaged with technology through auditory feedback, feedback was linked to music and performance whereas when they engaged with technology mainly through visual feedback, feedback focused on technology. Interestingly, feedback on music and performance as usually found in traditional one-to-one piano learning and teaching settings was found in this research as well where real-time auditory feedback was also available during student performance. Similarly, participants who focused on additional auditory feedback may have adopted a pedagogical approach more approximate to that used in a conventional piano studio. The engagement of participants could be either predominantly visual or auditory for use with real-time or post-hoc feedback.

A model for the pedagogical uses of technology-mediated feedback in HE piano learning and teaching is proposed in Figure 12.4. The application of technology-mediated feedback was possible because the technology system involved in this study—in terms of digital piano, MIDI interface, DAW software, laptop, additional PC screen—generated the additional visual and auditory feedback correspondent to the piano performances worked on in an HE piano studio.

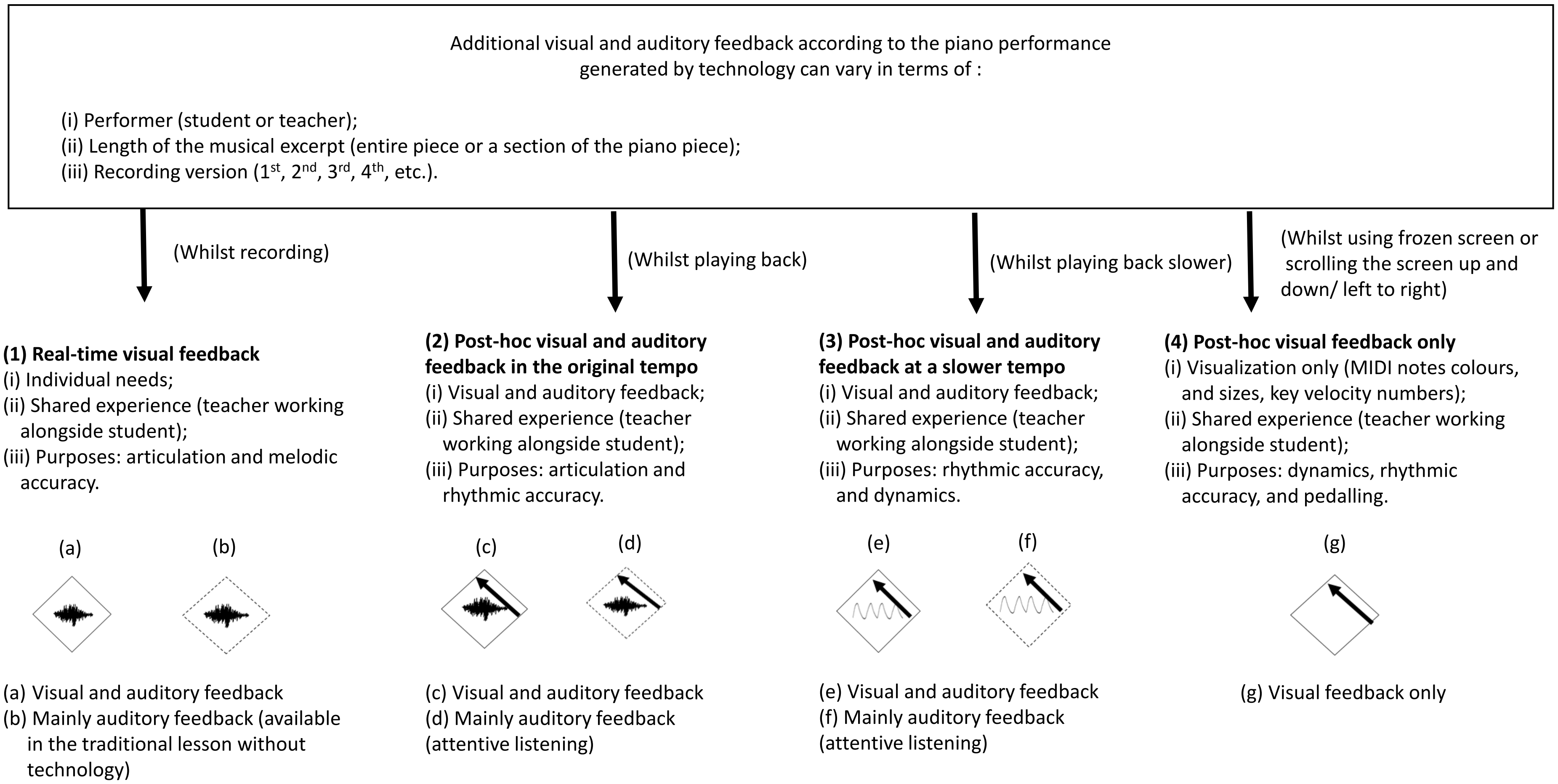


Figure 12.4 Model showing the pedagogical uses of technology-mediated feedback in HE piano learning and teaching

The third aim of the current study was to investigate whether the application of technology-mediated feedback in HE piano studios would enhance piano learning and teaching, and subsequently student performance. The third research question was answered based on findings of the video, MIDI and interview.

3. Does the application of technology-mediated feedback enhance higher education piano learning and teaching, and improve student performance in piano lessons?

In this in-depth study, the third research question asked whether the application of technology-mediated feedback in HE piano learning and teaching enhanced student learning and improved student performance in piano lessons. Three case studies were used to investigate patterns of feedback, their pedagogical use, and the usefulness or otherwise of additional visual and auditory feedback. Evidence suggested that types of verbal and non-verbal feedback when technology is applied in a piano studio can be delivered not only by teacher but also by the student through self-assessment. It was found that verbal and non-verbal feedback is related to music, performance, and technology which differentiates it from the type of feedback which is commonly found in conventional piano studios. Feedback on technology brings to the learning environment potential associations between technology and music by identifying the structure of the performed piano piece on the computer screen. Associations between technology and performance are also emphasized by the application of additional feedback in piano studios. The pedagogical use of technology-mediated feedback was seen to improve student learning and performance when a clear lesson focus was provided on musical performance parameters such as articulation or dynamics in a musical excerpt of the memorized piano piece.

By using technology-mediated feedback, students became more conscious of their own performances as they were able to compare their intended and actual performance outcomes. Conscious-awareness of performance outcomes was observed at two levels when technology-mediated feedback was applied in piano studios. The first level encompassed the associations between music and technology by identifying the music structure on the computer screen. The second level and higher clarified the associations between performance, such as dynamics and articulation, and technology, in terms of MIDI parameters, exemplified by MIDI notes colours and sizes, so as to improve student learning and performance.

Additional visual and auditory feedback varied in the following modalities: real-time and post-hoc; original and slower tempo; normal and silent mode. Additional feedback varied according to three aspects: performer, in terms of teacher or student generated; specific musical excerpts; and recording versions of performance-related data. These various modalities of additional visual and auditory feedback can augment sensorial feedback in the learning environment and impact on the intrapersonal feedback system. Associative learning might have augmented intrapersonal feedback and enhanced the student learning process through the additional sensorial feedback that was available in lessons. The additional visual and auditory feedback might provide associations with proprioceptive feedback in the intrapersonal feedback system, allowing students to become more conscious of their performance outcomes. Additional feedback generated by technology alongside teacher feedback might help to enhance learning through the associative learning in the visual-auditory-motor system, and support teaching by making students more conscious of their own performances. Differences were noted across case studies in the ways that students and teachers engaged with the technology. Some teacher and student pairs appeared to favour additional visual feedback whilst others appeared to favour additional auditory feedback. Teacher and student pairs which had engaged with technology for additional visual feedback were noted to deliver verbal and non-verbal feedback on technology, specifically MIDI parameters, alongside music and performance. Pairs which had interacted with technology for additional auditory feedback were noted as having delivered verbal and non-verbal feedback predominantly on music and performance. Although additional auditory and visual feedback was available to each pair, engagement with the technology-mediated feedback was context specific and dependent on individual differences in perception and levels of conscious-awareness.

Pedagogical uses of real-time and post-hoc feedback seemed to be applied in order to assist the improvement of student learning, and subsequently the enhancement of their performance for particular musical performance parameters. RTVF was useful for articulation: in terms of Alberti bass left hand legato, finger legato between chords, left hand arpeggio, chord attack and release; and melodic accuracy, for instance, missing notes. Post-hoc visual and auditory feedback was useful for: articulation, such as Alberti bass left hand legato; dynamics, for instance, dynamic balance between right and left hands; and rhythmic accuracy, in terms of rests between music sections. A potential use was revealed for pedalling as well. Prospective use on pedalling was also observed through associations between pedal responses, in terms of MIDI hold or soft pedals, and different pedalling frequencies and levels.

The use of technology-mediated feedback might not only support but also extend traditional approaches in HE piano studios since similar and different pedagogical approaches were evidenced through reports by teachers and students respectively. Perspectives on change in the learning process were perceived by both students and teachers when technology-mediated feedback was applied. Change in student learning processes was perceived particularly in relation to post-hoc feedback which provided opportunity to listen back to their recorded performance-related data as soon as they had finished playing. This facility accelerated the learning process.

Different perspectives on pedagogical approaches were found across participants when technology-mediated feedback was applied. Changes in pedagogical approach were perceived by students but not teachers. It is possible that either the teachers appeared not to have acknowledged change in their own teaching styles perhaps because they had not operate the technology, or, they were working to improve student learning and performance as they usually did in conventional one-to-one piano studio.

Based on these observations, a model of the effective application of technology-mediated feedback in HE piano studios shows characteristics which are either similar to or different from a conventional piano studio. The workflow of a conventional piano studio is shown at the bottom right side of the model. The different characteristics which incorporate the technology-based learning setting are shown at the top right side and left side of the model. The workflow of a technology-based learning setting when teacher and student pairs interact with the technology mainly through auditory feedback is shown on the top right side of the model. Here, verbal and non-verbal teacher feedback types are related to music and performance parameters. Thus, associations between music and performance are likely to happen when auditory feedback either in real-time (conventional studio) or post-hoc (technology-based studio) is used in piano learning. The workflow of when teacher and student pairs interact with the technology mainly through visual feedback either in real-time or post-hoc is demonstrated on the left side of the model. Here, verbal and non-verbal feedback types are related to technology and to the other two parameters—music and performance. Thus, associations between either technology and music, or technology and performance, are likely to occur when additional visual feedback generated by technology is applied in piano learning.

The effectiveness of this model depends on how each teacher and student pair interacted with the technology, and to what extent their interaction with technology was driven mainly through auditory feedback (top right side), visual feedback (top left side), a combination of both of them (both sides), or through maintaining the characteristics of a conventional piano setting (bottom right side). For example, case studies A and B seemed to have worked mostly on the left side of the model. Teacher and student A applied silent post-hoc visual feedback and post-hoc visual feedback combined with auditory feedback, with a clear lesson focus on articulation and dynamics. Teacher and student A identified the pedalling responses as MIDI notation but did not apply post-hoc visual feedback in order to improve student performance. Participants in case study B worked on the model mostly following real-time visual feedback with a clear lesson focus on melodic accuracy, and articulation. Teacher and student pairs in case study C worked mostly on the top right side of the model. Case study C seemed to have used post-hoc auditory feedback for the improvement of rhythmic accuracy. Case studies B and C demonstrated having worked on student performance by following a more traditional pedagogical approach (bottom right side).

Since there are usually multiple layers of feedback on the many musical performance parameters involved in a conventional piano studio, the application of technology-mediated feedback in an HE piano studio can decrease the discrepancies commonly noted between student and teacher views on learning priorities. A lesson focus that is clearer to both teacher and student can be achieved when using technology in HE piano studios by focusing on particular musical performance parameters through the additional feedback, through keyboard and pedalling activity, alongside teacher feedback. Student learning and performance can be improved for particular musical performance parameters, such as rhythmic accuracy, melodic accuracy, articulation, dynamics, and pedalling. Additional feedback can therefore augment intrapersonal feedback of students and enhance their conscious-awareness of their performance outcomes through visual-auditory-proprioceptive associations, and consequently enhance student learning and performance. Thus, there is a potential use of technology-mediated feedback in HE level piano studios alongside teacher feedback. The application of technology-mediated feedback seemed to optimize traditional pedagogical approaches, to promote additional visual and auditory feedback, and to make performance goals well-defined and lesson foci clearer in HE piano learning and teaching.

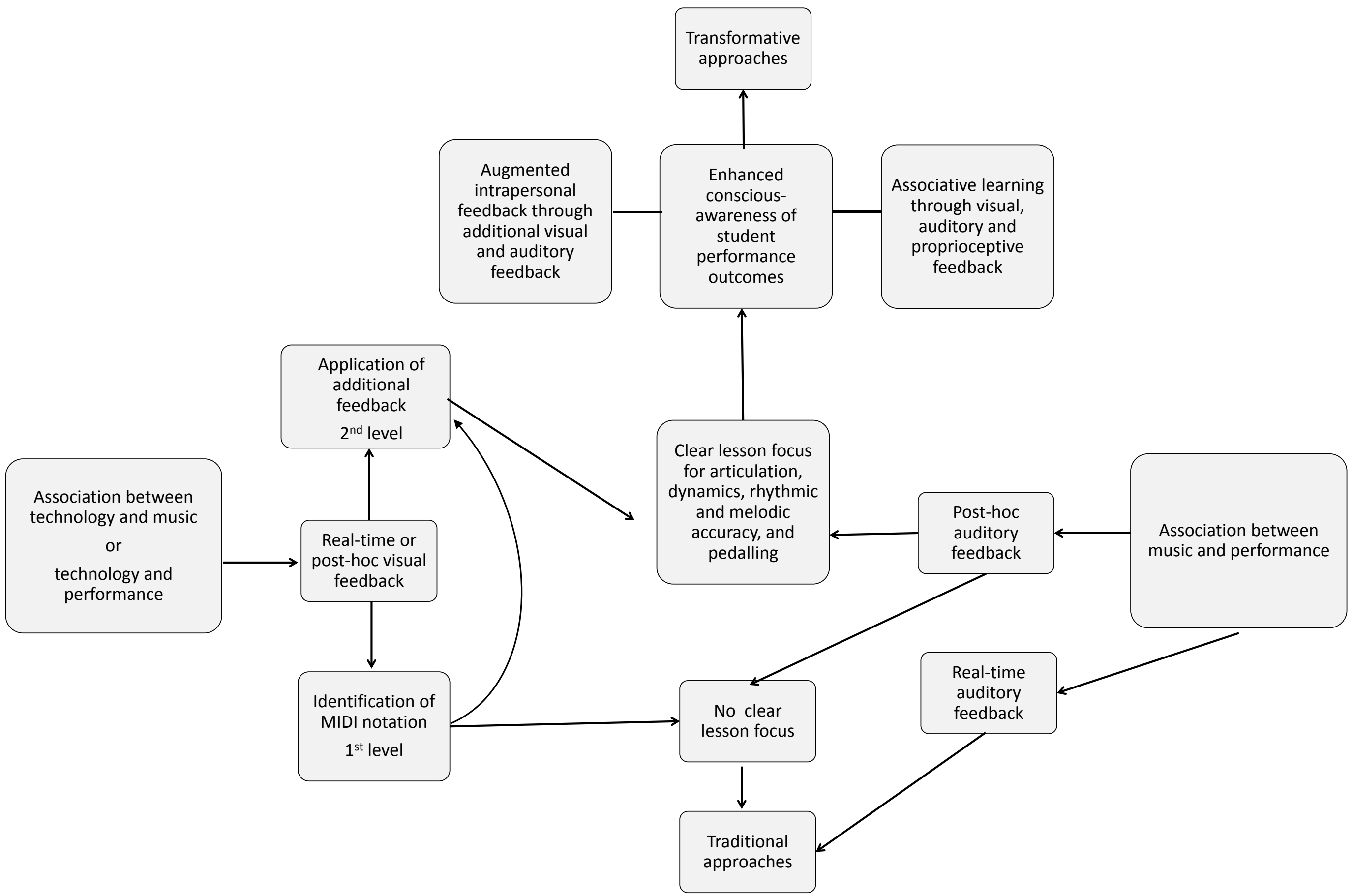


Figure 12.5 Model of effective application of technology-mediated feedback in HE piano studios

12.2 Implications for practice

The contribution of my study stems from the field of instrumental and vocal learning and teaching, specifically at HE level with the piano as principal or second instrument. I reviewed the literature on feedback, intrapersonal and interpersonal forms, in instrumental and vocal learning and teaching, which provided a theoretical framework of reference for this study. I developed a methodology to explore the use of technology-mediated feedback in HE piano learning and teaching using a novel design for data collection and production through an exploratory action case study approach. I also developed a multiple-method qualitative data analysis approach which combined five elements. First, video QDA was used to probe types of verbal and non-verbal feedback on music, performance and technology delivered by the student and teacher. Second, video QDA investigated the pedagogical uses of technology-mediated feedback over time. Third, video QDA examined the auditory feedback available in lessons. Specifically, microstructure analysis of musical behaviour, namely, musical practice and listening back to recorded data, was deployed in relation to the musical structure of the chosen piece. Fourth, MIDI QDA probed additional visual feedback available to participants regarding student keyboard and pedalling activity associated with music and performance. Fifth, interview QDA of teacher and student perspectives on their experiences in piano lessons with the application of technology-mediated feedback complemented video, including MIDI, QDA. These five methods intermeshed to provide in-depth insights into technology-mediated feedback in HE piano learning and teaching.

Evidence suggests that the application of technology-mediated feedback can be beneficial to traditional one-to-one piano learning and teaching. Findings of this study agree with the rationale and outcomes of previous research on RTVF use in singing studio (Welch, 1983, 1985b; Welch et al. 2005). Agreed findings share the evidence that using technology in music studio enables the teacher and student to access student performance outcomes in real-time, and also to save, store and playback the recording for subsequent review and comparison. However, the current study extends the reviewed literature by revealing how performance-related data in real-time can also be useful as post-hoc feedback in enhancing student learning and performance. Post-hoc feedback alongside teacher feedback was viewed as a potential tool for making the student aware of their learning process and performance through the comparison of intended and actual performance outcomes.

Technology mediated-feedback might support and extend traditional approaches in HE piano learning and teaching, in agreement with previous studies on the use of technology in music education (Savage, 2007), and in HE music production studios (King, 2008). Technology-mediated feedback might also contribute to the improvement of student learning and performance through additional visual and auditory feedback, which extends findings of previous research (Benson, 1998; Daniel, 2001; Riley, 2005; Tomita & Barber, 2008; Welch et al., 2005; Zhukov, 2010). First, technology offers additional sensory feedback, something which is not usually available in a traditional one-to-one piano learning and teaching setting. The availability of real-time and post-hoc visual and auditory feedback might promote associative learning through the auditory-visual-motor system (Acitores, 2011; Edelman, 2001; Lahav et al., 2007; Mathias et al., 2015).

Second, the application of technology-based feedback in a piano studio might promote variability of practice to teacher and student (Welch, 1983, 1985a, 1985b; Welch et al., 2005), which alongside diverse types of meaningful feedback, such as verbal and non-verbal, and additional visual and auditory feedback, might support HE piano learning and teaching. Third, the improvement in student learning and performance might be related to clearer and well-defined lesson foci (Latham & Locke, 1979) promoted by additional visual and auditory feedback generated by the technology, alongside interpersonal feedback between teacher and student. With clear and well-defined performance goals, students might be able to self-assess their own performances (Daniel, 2001; Hattie et al., 1996; Riley, 2005; Zhukov, 2010), develop their self-regulatory skills (Nielsen, 2001; Zimmerman, 1998), and increase conscious-awareness of performance outcomes (Aditores, 2011; Damasio, 2012; Edelman, 2001). Well-defined performance goals can accelerate the learning process for particular musical parameters such as articulation, dynamics, rhythmic accuracy, melodic accuracy, and pedalling.

In this study, technology-mediated feedback seemed to be a potentially effective tool for both students and teachers, whether used separately as visual or auditory feedback or as visual and auditory feedback combined. For students, technology use might support critical reflection on their own performances, and encourage independent self-evaluation. For teachers, the application of technology in piano studios might be a tool to promote self-evaluation of the effectiveness of their feedback on student performance. When both student and teacher pairs engage with auditory or visual cues, a collaborative space can be created in piano studios where teachers can reflect on their pedagogy and feedback, and students can reflect critically on their actual performances from a new perspective. As stated above, applied technology in piano studios affords students opportunity to self-assess their performance outcomes by listening back to recorded data and seeing the visual representation of performances on a computer screen. In this way, students are also able to compare intended and actual performance outcomes.

The models of feedback patterns in this study (see Figure 12.1) have demonstrated the nature of feedback in piano studios, the pedagogical use of additional feedback, and the effective application of technology-mediated feedback in piano learning and teaching. These models represent how technology can be applied in a piano studio, and its similarities with and differences from conventional one-to-one piano lessons. The research corroborates the findings of other studies regarding the use of information technology in learning and teaching which ‘can radically increase the array of learning possibilities presented to each individual student’ (Twigg, 2003, p. 36). The research can also inform practice with music technology in HE piano studios.

In this study, findings illuminate the potential for the optimization of traditional pedagogical approaches in HE instrumental and vocal learning through additional visual and auditory feedback generated by the application of technology. In conclusion, the application of technology-mediated feedback shows itself to have considerable potential for practice as it assisted a better understanding of forms of feedback which are available to the student and teacher through an evidence-based study in HE piano learning and teaching.

12.3 Implications for policy

The implications of this study relate to policy at an institutional level. According to the majority body of research studies reported in this study, little has changed in HE instrumental and vocal learning and teaching in recent years. In terms of university policy, it seems that there is an urgent need for higher education institutions (HEI) to be up-to-date with the prospective use of technological devices in education that have been researched recently. Institutions also need to be prepared to adjust their policies and develop course programmes according to the findings reported in recent research studies in instrumental and vocal learning and teaching. This could be achieved not only by equipping HEI spaces with the technological devices previously researched, but also by making an effective use of such devices either by training staff in the use of appropriate technology, or by creating new and alternative onsite spaces with technology-related experts who could facilitate and support teachers and students in their other-than-traditional one-to-one learning activities. This is because technology seemed to have supported piano learning and teaching by augmenting visual and auditory feedback in piano studio through clear and well-defined performance goals and enhanced conscious-awareness of performance outcomes.

The current study explored the pedagogical uses of technology-mediated feedback in HE piano learning and teaching. The review of the literature addressed the recurrent inherent problems in instrumental and vocal learning and teaching in relation to the mismatch found between practices within the lessons and the views of teachers and students on their learning priorities. In response to this, this research project showed through an evidence-based study that there is a potential transformative change in instrumental and vocal learning when technology-mediated feedback is available to teachers and students, particularly in HE level piano studios. Findings of this study support the view that optimizing HE piano learning and teaching is possible through the use of technology. Divergences in perspectives between teachers and students can be minimized when technology is applied in a piano studio because additional visual and auditory feedback can bring clear lesson foci through associations between technology and performance. When the performance goals are clear in a shared experience between teachers and students, students can also enhance their self-assessment of performances and increase their conscious-awareness of the actual performance outcomes.

Technology as a potential learning tool for transforming learning and teaching in HE instrumental and vocal studio might also support the view of a report derived from a programme of research conducted by researchers at the Higher Education Academy (HEA) (Gunn & Fisk, 2013). This asserted that '[t]eaching excellence is at the centre of national and international higher education policy discourse' and is 'found in most countries policy documents' (Gunn & Fisk, 2013, p. 5). Particularly in the United Kingdom (UK), the 'higher education providers are increasingly seeking to demonstrate their excellence in teaching, as well as research' and encouraging students 'to make better use of information to make decisions about where and what they study' (Gunn & Fisk, 2013, p. 5). According to Jørgensen (2010), 'research into higher music education has come of age and deserves to be regarded as an important research contribution in a "new" and separate field of research' (Jørgensen, 2010, p. 78, original emphasis). The potential of this body of research in higher music education chimes with the belief that there is a need 'to give the institutions a better understanding of the educational resources and processes as well as all the other aspects of institutional life that influence the quality of the institutions' (Jørgensen, 2010, p. 79).

Recent studies in education, particularly in the field of music education, have set out their contributions in pointing out not only problems but also prospective solutions in educational systems (e.g. Carey et al., 2013; Creech & Gaunt, 2012; Welch et al, 2005). The role of policy makers, particularly at an institutional level, is to ensure effective learning and teaching in HE institutions (Gunn & Fisk, 2013). The aim of a shared understanding between policy makers and researchers should be that of educating individuals; this aim should remain central to all they do (Wyse, Hayward & Pandya, 2016). Thus, it would be beneficial to HE institutions to develop and improve their policy so as to be up-to-date with research findings and thence to support a better quality education environment.

12.4 Limitations of this study

As with all research projects, a number of limitations of this study need to be reported, particularly those pertaining to methodology, research design, data collection and analysis. It is necessary to acknowledge these limitations especially when considering that the study was systematically conducted by an individual researcher rather than by a research team. Although a professional transcription team assisted with this study, multi-methods QDA in terms of thematic analysis of videoed lessons and interviews, microstructure analysis of videoed lessons, and MIDI QDA, were solely conducted by myself. The study involved checking repeatedly and extensively the in-depth multi-methods qualitative data analyses, something that is extremely challenging for a single researcher. Although the qualitative data analyses were conducted systematically by myself, when such work is done by a single researcher, there is always the possibility of error. Given the nature of a PhD study, finding another researcher in the same field willing to review an in-depth qualitative data analysis was a challenge, although it would have provided enormous and valuable assistance.

A second limitation of this study relates to my knowledge regarding the technology system used in piano lessons. After gaining experience in conducting pilot studies with technology, I felt I understood the technology well enough to undertake this study.

Notwithstanding, I was slightly limited in my knowledge of the technology, in the sense that it was not possible for me to be fully aware of all the potential resources that the DAW software could provide. This might have interfered with or influenced the results of this study.

A third limitation of the study relates to the exploratory action case study approach adopted in this study, in that it focused on a relatively small number of cases, participant pairs, lessons, and selected piano pieces. There were only three case studies in HE piano learning and teaching: three piano teachers with one of their students. The number of the piano lessons per case study was two for each teacher and student pair, with an interval of five to ten days between them. The limitation of only having two lessons was noted: in the first lesson, the teacher and student pairs needed to adjust themselves to the situation; while only in the second lesson could the participants plan and explore the technology with more familiarity. The piano pieces were one movement of a classical sonata to be worked on throughout two consecutive piano lessons. Conventional one-to-one piano lessons tend to focus on different pieces for each lesson. This study differed slightly from this convention: it required teacher and student pairs to work on the same piece in order to investigate the application of the technology. Another challenge which put a constraint on the study was that of finding participants. An initial pool of eight participants in the UK and Brazil was formed in the data collection. Then, only three teacher and student pairs at HE level in Brazil were selected to be analysed and reported in this study since these participants met the original criteria of this study. The collected data from the remaining five pairs can be analysed and reported in future publications so that other potential uses of this technology system can also be revealed in terms of different levels of expertise, uses for non-memorized pieces and other genres of music, and applications to different stages of piano learning processes.

A fourth limitation was in relation to the research design, and the way in which prospective participants for the study were contacted. A preliminary questionnaire could have been conducted in the first stage of the research study in order to see if any of the respondents had already used this type of technology-mediated feedback in their real context. In addition, although the nature of feedback in HE piano learning and teaching was conducted in the first pilot study as an initial fieldwork stage, it might have been beneficial to have collected data from one piano lesson per case study without the technology in order to have a baseline of the teacher and student behaviours in their usual piano lessons, and in a condition closer to their natural environment. It would have been interesting to examine whether or not the application of technology modified teacher feedback, and to compare more accurately to what extent that feedback was impacted by the application of technology.

A fifth limitation is that this study involved a technology system which was unfamiliar in the customary student-teacher one-to-one HE piano lesson context. The technology system encompassed the use of a digital piano, MIDI interface, DAW software, computer screen, as well as two digital cameras for video observation and a voice recorder for interviews. The perspectives of participants regarding the differences between playing an acoustic rather than a digital piano was discussed in detail in the interview QDA as opposed to the video QDA. Video QDA finding showed rapid student adjustment to the new instrument in case study B which was perceived by the teacher, although the transition between instruments is expected to be routine for pianists who deal with this change ordinarily. When comparing types of piano, differences in sensitivity were reported by participants; this might also be related to the instrument that both piano teachers and students were more accustomed to using, the acoustic piano. Sensitivity differences related to sound response, pedalling, sonority, timbre, and resonance of harmonics. The use of digital piano might have influenced particular musical performance parameters which the teacher and student pairs worked on in lessons. Although a recent study (Costa, 2013) provides evidence that performances by piano students on digital pianos can be assessed by experienced pianists through their video recordings, particular musical performance parameters are perceived to be more successfully assessed than others. For example, dynamics and articulation rather than notably pedalling, una corda or damper pedal, timber and harmonic resonance can be readily perceived or assessed in digital piano performances (Costa, 2013).

Finally, there is a limitation on the findings where technology-mediated feedback might not be as beneficial when applied to students with a visual impairment, especially to those students with a colour vision deficiency, such as Daltonism. Such students are unlikely to be able to differentiate the colour range from green to red which is shown on the visual feedback. Visual feedback is also of little value to blind students or those with severe visual impairment. However, when applied to students with a partial hearing impairment, and whose auditory skills may be affected, additional visual feedback might enhance the learning experience. Additional visual feedback can benefit such students through augmenting intrapersonal feedback, particularly for auditory feedback, by the visual-auditory-motor system.

12.5 Further research

The findings, discussion and conclusion of this current study highlight the need for further research studies in instrumental teaching and learning, specifically at HE level with the piano as principal or second instrument. Such studies are necessary in order to understand better the patterns of feedback, their pedagogical uses, and the effectiveness of the application of technology in a piano studio.

The first point for future research may be to investigate the role of other types of technology in piano learning through lesson observation and interviews with teachers and students. Such technology could include audio and/or video recording and MIDI protocol. This would also be useful to help evaluate whether piano students can be potential visual, auditory, or proprioceptive learners once one or another type of technology is used. Although the technology system used in this study is not as immediate as other technological devices, for instance mobile phones, the contributions of the current study could be investigated. The application of mobile phones, for audio and video recordings of student performances, could be examined alongside teacher feedback since such devices also provide additional visual and auditory feedback. It might be beneficial to examine types of ICT, including internet applications, which have already been used by piano students at home and whether these could be applied in educational settings. Findings of a previous study (Cranmer, Potter and Selwyn, 2008, p. 43) suggested the need '[of developing] forms of classroom technology provision which fit better with the needs, values and experiences of young people' when comparing ICT uses by young pupils at home and in primary school settings. The purposes of using technology could also be investigated, to examine how technology can be used in lessons alongside teachers and at home for self-study of students. In addition, technology can be used to remind students of their practice in lessons for use in self-study at home, to keep a record of student learning progress, as well as to keep a record of teacher modelling.

The second point for future research could be the possible application of this type of technology at other levels of piano expertise such as beginners or intermediate level students, and also in advanced levels. It might also work with other types of repertoire in exploring the more suitable musical performance parameters to be worked on in those cases, and to explore other potential uses of the technology. In addition, it would be valuable to investigate the prospective difference in terms of transfer or transformative pedagogical approaches between principal and second instrument learning in HE. It might be worth investigating what would encourage teachers to apply technology in their instrumental or vocal lessons, or specifically in piano lessons, and to examine what would encourage students to use technology in their own self-study, at home, for example, for self-evaluation. Findings of this study also suggest it would be worth examining whether this type of technology can enhance the learning of those individuals with visual or auditory impairment and thus evaluate whether additional auditory and visual feedback can support such individuals and benefit their learning.

The third point for future research is to examine whether or not the application of technology-mediated feedback could have an impact in distance learning environments. This study may thus be used to supplement findings of a previous study which found benefits of pedagogical uses of technology in distance learning in acquiring piano sight reading skills (Pike & Shoemaker, 2013), and in using Google Chat in developing piano expertise (Henley et al, 2016). The investigation of how audio and video recording files, including MIDI data, could be used in distance learning through Google Chat, Skype or What's App could be of benefit as well. Pike also reported in an interview that the visual displays from the technology used such as digital pianos, Internet MIDI software, and Skype video-conferencing technology, could have been used particularly for visual learners (Barancoski, 2014). This is because MIDI data can be generated, sent and received via the internet when using DAW software; it could therefore be of benefit in HE piano learning and teaching through video conferences or online learning platforms such as Moodle. Technology-mediated feedback could therefore also transform the master-apprenticeship type of relationship between teacher and student in a one-to-one piano learning environment for specific goals by 'enabling people to work cooperatively on initiatives which transcend hour and location' (Rees, 2002, p. 257).

The fourth point for future research would be to conduct a large-scale study based upon the approach used in this study. A longitudinal study across institutions can promote not only the training of the teaching staff but also further investigations into the pedagogical uses of technology in piano studios. First, promoting a CPD programme training courses to piano teachers alongside their students, with either face-to-face or on-line learning environment support, can make teacher and students more familiarized with both the technological system and also how they can apply it more independently by themselves. Second, the pedagogical uses of technology could be investigated more systematically in terms of frequency of technology use throughout an Academic Year (see Appendix 13). Other aspects which could be investigated might include student performance levels of expertise, and whether it is adequate for student learning processes such as sight-reading, reading, or memorizing the piece, and genres of music which would be more likely to be benefit from the application of this technology system (see Appendix 13).

The fifth point for future research relates to the use of a music score by teachers when student performance has already been memorized. There is a need to understand better the role of a music score in piano lessons by comparing lessons with and without the allowance of musical notation for the teacher while the student performs the entire piece from memory.

Finally, the last point that might be of interest in research in music education is the investigation of anxiety in instrumental and vocal learning. Several studies examine performance anxiety before, during, and after a performance; however, there do not seem to have been any research studies about stress management or anxiety of students during, for example, instrumental and vocal lessons. Performance anxiety might also be related to other-than performance reasons, such as the anxiety which students feel in their lessons alongside their teachers, so anxiety gets transferred to the performance setting. Anxiety in instrumental and vocal studios could be investigated in order to be prevented and to find out the most appropriate matches between learning and teaching styles by students and their teachers.

The implications for practice and policy when using technology-mediated feedback in HE piano learning are crucial since technology is a tool which can bring a clear lesson focus to learning and teaching. Technology can generate additional forms of feedback which can in turn augment intrapersonal feedback. Additional visual and auditory feedback alongside teacher feedback is a transformative pedagogical approach which can enhance student conscious-awareness of their performance outcomes, through comparing intended and actual performance outcomes. Technology use, subsequently, can improve student learning and performance.

Limitations of this study aimed to highlight points which could have impacted on the study, and where the current research design could have been improved upon. Limitations and further research sections also provided guidelines for future researchers who might be interested in investigating the pedagogical uses of technology in instrumental and vocal learning and teaching, or research projects in the same field. Despite the limitations of the study, the findings of this research project contribute to knowledge in the following ways.

First, this study contributes by providing a theoretical framework of reference for feedback in piano learning. Second, the study contributes the development of a novel methodology by using an exploratory action case study approach, and an innovative multi-methods approach of data collection and analyses. Third, it extends the reviewed literature by revealing that not only RTVF but also post-hoc visual and auditory feedback generated by technology can benefit instrumental and vocal learning and teaching, given that the use of additional feedback has been shown to augment intrapersonal feedback and enhance conscious-awareness of performance outcomes. Finally, this study contributes to the attempt to transform and optimize traditional pedagogical approaches in order to minimize differences in the perspectives between teachers and their students on learning priorities, by making performance goals well-defined and lesson focus clearer. It also paves the way for further research to be done and so enhance current teaching and learning practices within HE piano studio settings.

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Appendices

Appendix 1 Ranking questionnaires used in pilot study 1

Questionnaire for Piano Students Sair deste questionário

From your perspective as a piano student, please rank the following elements of piano performance in order of perceived learning difficulty

	least						most difficult
Timing							
Articulation							
Fingering							
Phrasing							
Rhythmic Accuracy							
Melodic Accuracy							
Dynamics							
Rubato							
Pedalling							
Tone quality							
Musical Structure							
Emotional Expression							
Interpretation							
Style							
Overall Flow							

Concluído

Key: The 7 point Likert scale ranking questionnaires used in pilot study 1 – applied to students

Questionnaire for Piano Teachers

Sair deste questionário

From your perspective as a piano teacher, please rank the following elements of piano performance in order of perceived learning difficulty

	least						most difficult
Timing							
Articulation							
Fingering							
Phrasing							
Rhythmic Accuracy							
Melodic Accuracy							
Dynamics							
Rubato							
Pedalling							
Tone quality							
Musical Structure							
Emotional Expression							
Interpretation							
Style							
Overall Flow							

Concluído

Key: The 7 point Likert scale ranking questionnaires used in pilot study 1 – applied to teachers

Appendix 2 Protocol script for the main study – video observations

Before arrival of participants:

The music technology suite will be set up in advance of the teaching session start time (an hour earlier than the session, on the same day of the teaching session). One camera will be placed behind the student in order to capture the additional computer screen, i.e. the one in front of the student. The other camera will be placed on the right side of the student in order to capture the behaviours of the three participants (student, teacher and researcher). The audio recorder will be placed on a table close to the three participants. The laptop will be connected to the digital piano through MIDI interface and also connected to the additional computer screen. The pieces of equipment will be tested, the size of the real-time visual feedback will be customized (to be made clearer and bigger), and a new project on *Reaper* will be created and saved; it will be named with the date of the session, e.g. November 13th 2013 (morning).

After arrival of participants:

1. The researcher will give the leaflets (information sheets) and consent form to be carefully read and signed by the two participants.

2. The researcher will remind participants that this research project received ethical approval at the IOE with the assurance that the data will be given in confidence and will be anonymised in any subsequent reporting. All data will be kept on a laptop with a secure password and will be used for academic purposes only. The text will read:

    > “Thank you for accepting to participate in this research project. Just to remind you that the teaching session(s) will be video recorded (and audio recorded) and the interviews will be audio recorded. The collected data in this study will be treated with strict confidentiality, will be anonymised, and will be used for academic purposes only. The aim of this study is to explore the use of technology in two piano teaching

sessions for improving the performance of a memorized chosen piece or/and of a familiar piano piece on which teacher and student have been working together. The plan would be: we record the performance of the entire piece, we play it back, and I would be asking what you two would like to improve in the performance of this piece, and what you would like to do for that such as recording small excerpts or playing it back. I will also be showing what this technology can do."

3. The researcher will remind participants that the researcher's role as a participant-observer in the teaching session involves not only the manipulation of the technology (e.g. by starting a project, saving a project, recording the performance, playing it back, playing it back slower, zooming in and out, scrolling up and down, showing the note properties) but also providing information on technology (please see item 5), asking questions (please see item 6), and negotiating the focus or giving directions (please see item 7). The researcher will follow the teacher's and student's cues in order to give directions or negotiate the focus or task. For example, if an identified learning difficulty is found in the right hand passage, the researcher can suggest recording only RH or focusing on RH when playing back.

4. The researcher WILL NOT: (1) give feedback on the student's performance; (2) provide information or give directions on how the student needs to work on the performance in order to improve it; (3) play, model, sing, make gestures, or imitate the student's performance in order to improve it; and (4) explain why an unintended performance aspect (either interpretative or technical) is happening. The researcher will use back channelling when needed such as: "Mm, yeah, uhum," when teacher and student are talking, or when either of them are talking to the researcher.

5. The researcher will provide information on the technology during the teaching session when the student's performance is recorded or played back, for at least the first few times until the participants are familiar with the possibilities, as follows below:

> "When you are playing, the first type of screen is this (shows the interface for real-time, i.e. the black and white one) which appears in real-time, i.e. while you are playing. Have you noticed it? I would like to know at some point how we can use this as well. The second type of screen is this (shows the interface for post-hoc, i.e. the colourful one), which appears when playing back the recordings. Can I play it back? Would you like to hear and see what is happening?"

6. The researcher will be asking the questions as follows:

- What piano piece have you chosen to play from memory?
- What piano piece have you been working on which you want to play today?
- What would you like to improve in this performance? (after performing/recording or playing back)
- What have you noticed? (after performing/recording or playing back)
- Did you know that this (an aspect they want to improve) was happening?
- How have you noticed it (by listening or by seeing or both)?
- Why is this happening?

7. The researcher will also be intervening in the session by giving directions (or negotiating focus or tasks) through questions such as:

- Would you like to perform (and record) it again?
- Would you like to listen to it and see the playback?
- Would you like to listen to it and see the playback slower?
- Would you like to see both hands on the screen? (playing back at original or slower tempo, or looking at the frozen screen without sound)
- Would you like to focus on the RH? (playing back at original or slower tempo, or looking at the frozen screen without sound)
- Would you like to focus on the LH? (playing back at original or slower tempo, or looking at the frozen screen without sound)
- Would you like to focus on a section of the piece? Which section? Why? (playing back at original or slower tempo, or looking at the frozen screen without sound)

8. At the end of the session, the researcher will ask the teacher and the student:

- What would you like to focus on in this piece for the next session?
- How would you like to plan the next session?

The researcher will thank the participants and move on to the interviews.

Appendix 3 Protocol script for the main study – interviews

The researcher will ask the interviewee whether they feel comfortable to start the interview.

The researcher will remind the interviewee that this research project received ethical approval at the IOE with the assurance that the data will be given in confidence and will be anonymised in any subsequent reporting.

The researcher will tell the interviewee that they will be asked about: (1) their background in piano training, piano performance teaching and learning, and musical and technical aspects related to playing this specific piano piece; and (2) their impressions and experience acquired in the teaching session with technology.

The interview schedule for teachers and students in the main study shows prompts in *italics* for the added questions from the interview schedules applied in the pilot studies 5 and 6.

First interview schedule for the main study – teachers

Name (to be coded)

Gender

Age

Nationality

1. Tell me about your background:

    1.1 How was your piano training? Where have you studied and with whom?

    1.2 What do you do? What are you doing now?

    1.3 How long have you been teaching? How many students do you teach? For which ages and levels?

    1.4 How is your teaching strategy or style?

    1.5 What is your idea of an ideal piano lesson?

    1.6 Have you performed? Solo? Chamber music? Classical? Popular?

    1.7 Do you perform regularly? If so, for how long? Solo? Chamber music?

2. Reasons for participating in this research project:

    2.1 Why have you decided to take part in this research project with technology?

    2.2 How long have you been teaching this student?

    2.3 Is this student a private student?

    2.4 Where do you teach this student?

    2.5 How often are the piano lessons for this student?

2.6 Why have you chosen this particular student to take part in it?

2.7 Have you used any type of technology in your piano teaching? If so, what types and how have you used it?

2.8 Have you used any type of technology when practising for your performances? If so, what types and how have you used it?

3. Aspects of piano performance, student's performance and the chosen piece:

3.1 Which aspects of piano performance do you find the most difficult ones for teaching?

3.2 What are the aspects that you want this student to improve in piano performance in general?

3.3 Which pieces are you working on with this student? What are aspects that you and your student have been working on together recently in your piano lessons in order to improve piano performance? How have you been achieving it?

3.4 Why have you chosen this specific piano piece to work on in this teaching session with technology? How have you worked on it until now?

3.5 Which aspects of piano performance does this particular piece require working on?

3.6 What would you like to improve in the student's performance for this particular piece?

4. Teaching:

4.1 How do you usually work with a student in order to improve their performance?

4.2 How have you worked with this student in order to improve his/her performance for this session for this particular piece? For what purposes and focus?

- Verbal (providing information, giving directions, asking questions, general feedback, back channelling, off-task comments)?

- Non-verbal (playing/modelling, imitation of student's playing, singing alongside student's performance, making gestures (reinforcing the speech, conducting), making body gestures, facial expression, writing on score, pointing to the score, others)?

5. Use of technology:

5.1 How was your experience in this piano lesson with technology?

5.2 How was the application of this technology in this session?

- Real-time
- Post-hoc (playback) at the original tempo
- Post-hoc (playback) at a slower tempo
- Frozen screen

5.3 For which purposes or focus was this technology used?

5.4 *What are your impressions of the use of this technology in a piano lesson?*

5.5 *Has this technology changed your teaching style? (Or the way you teach or your pedagogical approach)? If so, how and for which aspects (musical or technical)?*

5.6 *Has this technology changed the learning style of your student? If so, how and for which aspects (musical or technical)?*

5.7 Could you tell me about the things which went well in this session? And otherwise?

5.8 How do you feel about the presence of the researcher manipulating the technology *and participating in the session?* (As facilitator/ a disturbance?)

5.9 *If you had a chance for practice with this technology with your student, how would practise with it? For which types of pieces? For which stages of student learning process would you use the technology, for example when sight-reading, memorizing, etc?*

5.10 How much would this piece of technology be incorporated into a piano lesson, in your opinion?

5.11 Would you recommend it to your student for his/her own private piano practise? If so, how? If not, why?

5.12 Is there anything else you would like to say about this session that I haven't asked you?

Thank you for your time and participation in this project, it was very interesting!

First interview schedule for the main study – students

Name (to be coded)

Gender

Age

Nationality

1. Tell me about your background:

1.1 What do you do?

1.2 How long have you been studying piano?

1.3 How was your piano training? Where have you studied and with whom?

1.4 How long have you been studying with this teacher? How is his/her teaching strategy or style?

1.5 What have you been studying? Which piano pieces (repertoire) have you been studying?

1.6 Have you ever taught piano? If so, how long have you been teaching, and for which levels and ages?

1.7 *What is your idea of an ideal piano lesson?*

2. Reasons for participating in this research project:

2.1 Why have you decided to take part in this research project with technology?

2.2 How long have you been studying with this teacher?

2.3 Do you have private lessons?

2.4 Where do you have your piano lessons (your home, teacher's studio, school)?

2.5 How often do you have your piano lessons with your teacher?

2.6 Have you ever used any type of technology in your piano practise? If so, what types and how have you used it?

2.7 Have you performed to an audience yet? Have you used any type of technology when practising for your performances? If so, what types and how have you used it?

3. Aspects of piano performance, student's performance and the chosen piece:

3.1 Which aspects of piano performance do you find the most difficult ones for learning?

3.2 What are the aspects you want to improve in your piano performance in general?

3.3 Which pieces are you working on with your teacher? Which aspects have you and your teacher been working on together recently in lessons in order to improve piano performance? How have you been achieving it?

3.4 Why have you chosen this specific piano piece to work on in this teaching session with technology? How have you been working on it prior to this teaching session?

3.5 Which aspects of your playing would you like to improve in general (either musical or technical aspects)?

3.6 What would you like to improve in your performance for this particular piece? If you were able to change your performance, what would you change?

4. Teaching:

4.1 How do you usually work with your teacher in order to improve your performance?

4.2 How was teacher feedback for this session? How did you feel about teacher feedback on your performance for this particular piece? For which purposes or focus?

- Verbal (providing information, giving directions, asking questions, general feedback, back channelling, off-task comments)
- Non-verbal (playing/ modelling, imitation of student's playing, singing alongside student's performance, making gestures (reinforcing the speech, conducting), making body gestures, facial expression, writing on score, pointing to the score, others)

5. Use of technology:

5.1 How was your experience in this piano lesson with technology?

5.2 What is your impression about the use of technology in this session? How was the application of this technology in this session?

- Real-time
- Post-hoc with original tempo
- Post-hoc with slower tempo
- Frozen screen

5.3 For which purposes was this technology used?

5.4 What are your impressions on the use of this technology in a piano lesson?

5.5 Has this technology changed the way you learn? If so, how and for which aspects (musical or technical)?

5.6 Has this technology changed the teaching style (teaching approach) of your teacher? If so, how and for which aspects (musical or technical)?

5.7 How much would this piece of technology be incorporated into a piano lesson, in your opinion?

5.8 Could you tell me about the things which went well in this session? And otherwise?

5.9 How do you feel about the presence of the researcher manipulating the technology *and participating in the session?* (As a facilitator/ disturbance?)

5.10 If you had a chance for practice with this technology, how would you practise with it? For which types of pieces? For which stages *of your learning process would you use the technology, for example when sight-reading, memorizing, etc?*

5.11 Is there anything else you would like to say about this session that I haven't asked you?

Thank you for your time and participation in this project, it was very interesting!

Second interview schedule for the main study – teachers

1. *Tell me about the musical and technical aspects covered in this session*.
2. *What was covered in relation to this specific chosen piece (musical and technical aspects)?*
3. *How have you (teacher) covered them (the musical and technical aspects)?*
4. *What were the teaching strategies which you used in order to improve your student's performance (without the technology)?*
5. *Tell me about your experience in this session.*
6. *What is your impression of using technology in this session?*
7. *How was the application of this technology in this session? For which focus or purposes?*
    - Real-time
    - Post-hoc with original tempo
    - Post-hoc with slower tempo
    - Frozen screen
8. *Which musical or technical aspects were better identified with the use of technology (e.g. evenness, dynamics, pedalling, timing, etc)? How was the application of technology for these aspects? What types of screen (real-time, post-hoc, frozen screen) have you used and for which purposes?*
9. *Have you perceived any change in your teaching style when using this technology? If so, how?*
10. *Have you perceived any change in the student's learning process when using this technology? If so, how?*
11. *What are the differences across the teaching sessions using the technology?*
12. *What are the similarities across the teaching sessions using the technology?*

13. What are the differences across the teaching sessions using the technology?

14. How was the pedagogical process along these sessions?

15. If you could improve it, how would you plan a piano lesson using this technology?

16. Do you have anything else you would like to tell about your experience in this research project?

Thank you for your time and participation in this project, it was very interesting!

Second interview schedule for the main study – students

1. *Tell me about the musical and technical aspects covered in this session.*
2. *What was covered in relation to this specific chosen piece (musical and technical aspects)?*
3. *How did your teacher cover them (the musical and technical aspects)?*
4. *What were the teaching strategies which your teacher used in order to improve your performance (without the technology)?*
5. *Tell me about your experience in this session.*
6. *What is your impression of using technology in this session?*
7. *How was the application of this technology in this session? For which focus or purposes?*
    - Real-time
    - Post-hoc with original tempo
    - Post-hoc with slower tempo
    - Frozen screen
8. *Which musical or technical aspects were better identified with the use of technology (e.g. evenness, dynamics, pedalling, timing, etc)? How was the application of technology for these aspects? What types of screen (real-time, post-hoc, frozen screen) have you used and for which purposes?*
9. *Have you perceived any change in your teacher teaching style when using this technology? If so, how?*
10. *Have you perceived any change in your learning style when using this technology? If so, how?*
11. *What are the similarities across the teaching sessions using the technology?*
12. *What are the differences across the teaching sessions using the technology?*

13. *How was your learning process along these sessions?*

14. *If you could improve it, how would you plan a piano lesson using this technology?*

15. *Do you have anything else you would like to tell about your experience in this research project?*

Thank you for your time and participation in this project, it was very interesting!

Appendix 4: Information leaflet to the participants of this study

Page 4

Do you have to take part?

Participation in the project is entirely voluntary and you can also withdraw at any time of the project with or without reason. If you decide to take part, it would be beneficial if you please contact your piano student (or your piano teacher) in advance to make sure that both agree. Then, send me a message by email confirming that you and your student (or teacher) will take part in this research project. Then, I will send you back the consent form to be completed and signed.

Will you know about the research results?

If there is an interest on the research results you may ask me so that I can send you a message by email about any related publication. Once the PhD thesis is completed, it will be available online at the British Library catalogue.

Who is funding the research?

The Brazilian Foundation CAPES (Higher Education Coordination Agency) has been supporting my PhD study since 2010.

The research project has been reviewed and received approval by the Faculty Research Ethics Committee at the IOE.

Thank you for reading this leaflet.

Contact details:

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07854 212118

Page 1

IOE LONDON
Leading education and social research
Institute of Education
University of London

The use of technology to enhance feedback in advanced level piano learning and teaching

A research project

November 2013 - February 2014

Information for teachers
Please will you help with my research?

My name is Luciana Hamond. I am a Brazilian Doctoral Student at the Institute of Education (IOE), University of London.

This leaflet explains my PhD research focus. I would be pleased to answer any questions that you have.

I am currently undertaking the final fieldwork phase of my PhD which is focused on the use of technology (and more importantly the usefulness of the feedback it provides) in the course of advanced level piano instrumental lessons.

At the moment I am seeking participants (piano teachers and their students) for my research project in order to gain their insights into the use and usefulness of technology in the context of piano learning and teaching.

I would really appreciate it if you could take part in my research.

Page 2

Who will be in the project?

The participants will be the **piano teacher and one student** (Grade 8 or above) who have been working together for at least one term, and have been working on a memorized piece, **plus the researcher (myself)** who will be supporting teacher and student in a collaborative way in the teaching sessions.

What will happen during the research?

The teaching sessions with the use of technology will be video and audio recorded. After the teaching sessions the participants will be interviewed and have their interviews audio recorded. The technology in this study involves a digital piano connected to a laptop computer, running a software (Cockos' Reaper) via a MIDI interface. Participants will have the opportunity to use this technology during the course of a minimum of 2 (two) piano lessons, whilst working on a memorized piece. The intention is to run more than one session with the technology so that the participants can apply their experiences across sessions. The first session will demonstrate the system and explore the understanding of this technology in a practical context. Then, the subsequent session(s) aims to explore how the technology can be used by teacher and student for improvements of certain either musical or technical aspects of a memorized chosen piece.

What questions will be asked?

In the interviews, the participants will be asked to answer questions about: (1) their background; (2) the aspects they have been working on together recently and others they want to improve in piano performance; and (3) their impressions on their experience with the technology in the sessions.

Where will the teaching sessions be conducted?

The teaching sessions will be conducted at the Institute of Education (IOE), University of London, 20 Bedford Way, WC1H 0AL, London, UK. Nearest tube stations: Russel Square (Piccadilly Line), and Euston (Victoria and Northern Lines). Expenses will be covered (please keep the receipts).

Institute of Education, University of London
20 Bedford Way, WC1H 0AL, London, UK.
Nearest tube stations: Russel Square (Piccadilly Line),
and Euston (Victoria and Northern Lines).

Page 3

What will happen to you if you take part?

Once you agree to take part in this research project, you will be asked to send a message by email to the researcher about your decision. Then arrangements will be made regarding convenient dates and times for you and your teacher (or student) to participate. After reading the information in this leaflet, the participants will be asked to complete and sign a consent form for this study.

Could there be problems for you if you take part?

This research project involves no known physical or psychological risks. If you agree to take part in this research project, I hope you have an enriched experience.

Will doing the research help you?

Two previous pilot studies have shown that the use of this technology in piano lessons may help the student and teacher to improve certain aspects of the student's playing of a particular piece. This technology can provide feedback on certain aspects of piano performance which may initially be outside the student's conscious awareness. It seems that the presence of the researcher manipulating the technology at the request of the dyad may also help the teacher and student.

Who will know that you have been in the research?

The research received ethical approval at the IOE with the assurance that the data will be given in confidence and will be anonymised in any subsequent reporting, i.e. the participants' names will be changed or will receive a number (student 1, teacher 1, for example). In addition, the participants can withdraw from the research at any time. The collected data (video and audio recordings) will be kept in a laptop with a secure password and will be used for academic purposes only.

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University of London

Appendix 5 Consent form from participants of this study

CONSENT FORM

Name of Project: ***The use of technology to enhance feedback in advanced level piano learning and teaching***

Name of Researcher: **Luciana F. Hamond**

Contact details:

Address:

Tel:

Email:

Start and end dates: October 2013 – February 2014

Please initial box

1. I confirm that I have read and understood the leaflet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
3. I understand that any personal information that I provide to the researchers will be kept strictly confidential.
4. I give my permission for my piano lesson with technology to be observed and to be video and audio recorded.
5. I agree to be interviewed and give permission for my interview to be audio recorded.
6. I agree to take part in the above study.

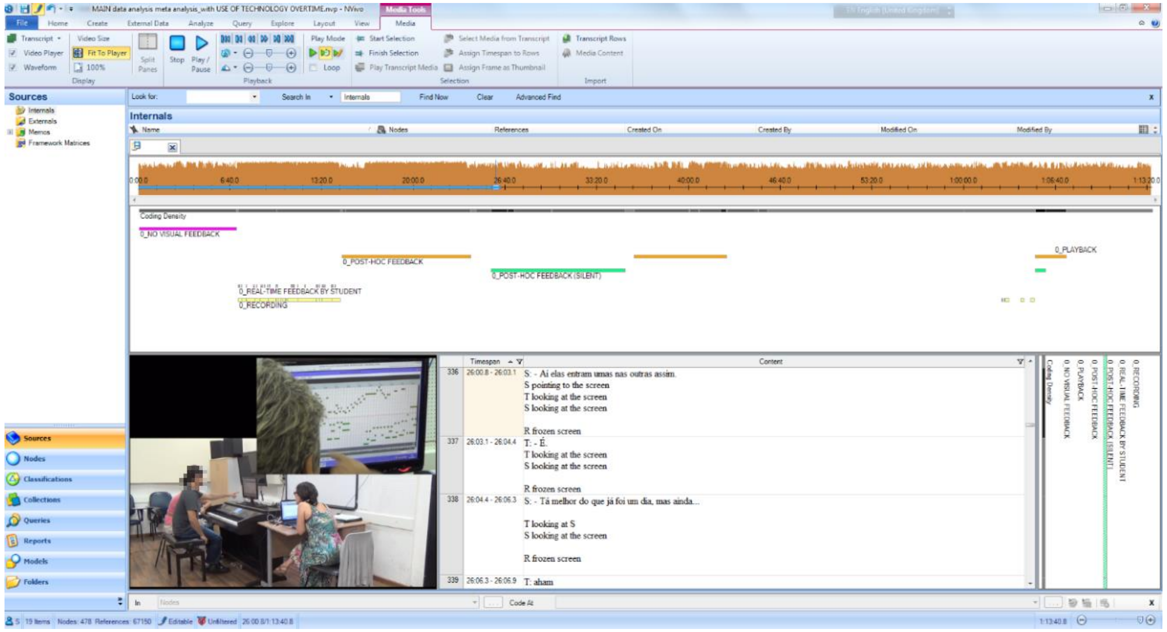
Participant's name:

Signed: date:

Researcher's name:

Signed: date:

Appendix 6: Example of CAQDA software (NVivo10) navigation interface



Key: NVivo10 interface of case study A lesson 1: (1) on the left side: the two-shot video; (2) in the middle: timespan, and content with the written transcription of verbal and non-verbal behaviours of participants; (3) waveform of audio recording of the video alongside the lesson timeline; and (4) on the right and alongside the timeline: the coded categories for use of technology-mediated feedback

Appendix 7: Meta-category of verbal behaviours in this study

VERBAL BEHAVIOURS INCLUDING FEEDBACK - SUB-CATEGORIES	Definition
ANSWERING	Short answering a question
ASKING QUESTIONS	Questioning, enquiring, clarifying question
BACKCHANNELLING	Saying “uhum” , “yeah”, “Mm”
COMMENTING ON PREVIOUS EXPERIENCES	Telling a story of something the teachers remembered during the lesson and also related to a previous experience in their lives
EMOTIONAL RESPONSES	Positive, negative or ambiguous responses regarding either the use of the technology or pedagogical (or technical) difficulty
GENERAL FEEDBACK	Positive, negative or ambiguous feedback, such as “very good”, “it is not”, or “it is better but it is not good”
GIVING DIRECTION	Recommending or asking someone to do something, or music related ones such as counting whilst perfoming, saying name of notes, and saying “ta-ta-ta” or "blem-blem", saying the finger numbers aloud
OFF-TASK COMMENTS	Talking about informal subject, such as what happened in the day before, arranging the day and time of the interview, deciding the position of the chair, etc.
OTHER VERBAL BEHAVIOURS	Apologising, thanking, agreeing, disagreeing, saying "tsc"
PLANNING THE SECOND SESSION	Making a plan for the second lesson
PROVIDING INFORMATION	Providing information on what they see on the computer screen, self-evaluation on own performance, completing other participant's sentence, commenting on digital piano, providing information on student's performance, on music score, on digital piano, on general aspects, on technology, and on instructional feedback.

Key: This table shows the list of 11 sub-categories of verbal behaviours (including feedback) which were related to the participants (teacher, student, and researcher) across case studies.

Table of sub-categories of verbal behaviours in case study A, lesson 1 and lesson 2

Teacher's *verbal* behaviours including feedback	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
T V PROVIDING INFORMATION	213	19.49%	198	17.59%
T V ASKING QUESTIONS	78	4.35%	52	3.23%
T V GIVING DIRECTIONS	54	3.20%	77	5.68%
T V BACK-CHANNELLING	87	3.06%	45	1.50%
T V EMOTIONAL RESPONSES	38	2.97%	29	2.12%
T V PLANNING SECOND SESSION	14	1.42%	0	0.00%
T V COMMENTING ON PREVIOUS EXPERIENCES	11	1.03%	64	5.69%
T V OFF TASK	16	0.84%	5	0.21%
T V ANSWERING	17	0.83%	8	0.40%
T V OTHER VERBAL BEHAVIOURS	9	0.50%	14	0.53%
T V GENERAL FEEDBACK	2	0.19%	11	0.42%
sum	539	37.89%	503	37.37%

Student's *verbal* behaviours including feedback	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
S V PROVIDING INFORMATION	101	6.37%	70	4.76%
S V ASKING QUESTIONS	27	2.20%	19	1.05%
S V BACK-CHANELLING	55	1.76%	108	3.65%
S V ANSWERING	21	0.98%	17	0.82%
S V GIVING DIRECTIONS	17	0.94%	27	1.20%
S V EMOTIONAL RESPONSES	17	0.94%	17	0.97%
S V OTHER VERBAL BEHAVIOURS	13	0.60%	18	0.65%
S V COMENTING ON PREVIOUS EXPERIENCES	5	0.34%	0	0.00%
S V OFF TASK	3	0.17%	1	0.02%
sum	259	14.31%	277	13.10%

Researcher's *verbal* behaviours including feedback	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
R V PROVIDING INFORMATION	58	6.67%	33	2.19%
R V GIVING DIRECTION	30	1.50%	12	0.70%
R V ASKING QUESTIONS	26	1.45%	20	0.99%
R V BACK-CHANELLING	31	1.35%	26	0.64%
R V OFF TASK	14	1.16%	2	0.10%
R V ANSWERING	11	0.54%	14	0.34%
R V OTHER VERBAL BEHAVIOURS	3	0.19%	8	0.33%
sum	173	12.87%	115	5.30%

Key: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed verbal behaviours in lesson 1 (4420 seconds) and in lesson 2 (3831 seconds), when using a CAQDA software NVivo10.

Table of sub-categories of verbal behaviours in case study B, lesson 1 and lesson 2

Teacher's *verbal* behaviours including feedback	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
T V PROVIDING INFORMATION	188	18.97%	195	17.70%
T V GIVING DIRECTIONS	152	10.78%	113	8.18%
T V OFF TASK	33	3.59%	36	3.80%
T V GENERAL FEEDBACK	48	2.49%	50	2.41%
T V EMOTIONAL RESPONSES	19	1.90%	43	3.72%
T V ASKING QUESTIONS	18	1.63%	15	0.82%
T V PLANNING SECOND SESSION	9	1.21%	0	0.00%
T V BACK-CHANNELLING	21	1.09%	7	0.40%
T V OTHER VERBAL BEHAVIOURS	4	0.30%	23	1.01%
T V ANSWERING	8	0.30%	11	0.56%
T V COMMENTING ON PREVIOUS EXPERIENCES	0	0.00%	24	2.54%
sum	500	42.26%	517	41.14%

Student's *verbal* behaviours including feedback	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
S V BACK-CHANELLING	38	2.09%	29	2.00%
S V PROVIDING INFORMATION	21	1.50%	43	2.65%
S V OFF TASK	13	1.04%	17	1.48%
S V ASKING QUESTIONS	14	0.78%	12	0.66%
S V ANSWERING	8	0.57%	6	0.30%
S V GIVING DIRECTIONS	6	0.46%	11	1.02%
S V OTHER VERBAL BEHAVIOURS	7	0.38%	12	0.60%
S V EMOTIONAL RESPONSES	3	0.09%	29	1.35%
S V COMENTING ON PREVIOUS EXPERIENCES	1	0.04%	2	0.21%
sum	111	6.97%	161	10.28%

Researcher's *verbal* behaviours including feedback	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
R V PROVIDING INFORMATION	14	2.89%	7	0.40%
R V ASKING QUESTIONS	16	1.15%	17	1.04%
R V OFF TASK	19	1.14%	22	1.46%
R V GIVING DIRECTION	8	0.82%	4	0.36%
R V BACK-CHANELLING	13	0.64%	12	0.68%
R V OTHER VERBAL BEHAVIOURS	7	0.39%	5	0.28%
R V ANSWERING	4	0.28%	1	0.07%
sum	81	7.31%	68	4.29%

Key: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed verbal behaviours in lesson 1 (2951 seconds) and in lesson 2 (2677 seconds), when using a CAQDA software NVivo10.

Table of sub-categories of verbal behaviours in case study C, lesson 1 and lesson 2

Teacher's *verbal* behaviours including feedback	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
T V PROVIDING INFORMATION	179	15.12%	210	17.22%
T V GIVING DIRECTIONS	239	17.31%	255	17.78%
T V ASKING QUESTIONS	73	4.96%	45	2.93%
T V GENERAL FEEDBACK	41	2.11%	78	3.25%
T V OFF TASK	19	1.90%	8	0.55%
T V PLANNING SECOND SESSION	18	1.48%	0	0.00%
T V BACK-CHANNELLING	31	1.45%	16	0.84%
T V ANSWERING	13	0.82%	13	0.76%
T V EMOTIONAL RESPONSES	10	0.81%	9	0.88%
T V OTHER VERBAL BEHAVIOURS	5	0.41%	6	0.35%
sum	628	46.37%	640	44.57%

Student's *verbal* behaviours including feedback	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
S V BACK-CHANELLING	72	4.40%	49	2.57%
S V PROVIDING INFORMATION	14	1.36%	8	0.76%
S V ANSWERING	10	0.71%	11	0.97%
S V ASKING QUESTIONS	8	0.66%	12	0.67%
S V OTHER VERBAL BEHAVIOURS	2	0.21%	4	0.20%
S V OFF TASK	1	0.11%	2	0.19%
S V GIVING DIRECTIONS	1	0.08%	2	0.13%
sum	108	7.53%	88	5.48%

Researcher's *verbal* behaviours including feedback	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
R V PROVIDING INFORMATION	33	5.15%	1	0.50%
R V GIVING DIRECTION	27	2.22%	7	0.09%
R V ASKING QUESTIONS	21	1.93%	14	0.96%
R V BACK-CHANELLING	23	1.45%	23	1.45%
R V OFF TASK	18	1.32%	8	0.47%
R V ANSWERING	10	0.59%	9	0.47%
R V OTHER VERBAL BEHAVIOURS	4	0.32%	2	0.18%
sum	136	12.98%	64	4.13%

Key: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed verbal behaviours in lesson 1 (2957 seconds) and in lesson 2 (3145 seconds), when using a CAQDA software NVivo10.

Appendix 8: Meta-category of non-verbal behaviours in this study

NON-VERBAL BEHAVIOUR INCLUDING FEEDBACK – SUB-CATEGORIES	Definition
BOUNCING BODY AND NODDING HEAD	Moving the body and/or head back and forth without a clear purpose or made unconsciously, perhaps denoting they are following, accompanying or marking the tempo whilst listening back to a performance or a recorded performance.
GESTURE	Making gestures by hand or foot which seemed to be with an intention or purpose: (a) silent gestures (without producing any sound) such as conducting or any music related gesture (to start playing, for legato, phrasing, dynamics, holding a note, pedal movement, tempo); (b) gestures with sound: rhythm or tempo related gestures such as clapping, snapping fingers and tapping (hand or foot); and (c) mute playing (simulating playing in a hard surface, i.e. table or piano lid) or air playing (simulating playing in the air).
LOOKING AT THE COMPUTER SCREEN	When the participant seemed to be looking at the computer screen whilst recording (real time feedback) or playing back (post-hoc feedback).
LOOKING AT THE MUSIC SCORE	When the participant seemed to be looking at the musical score.
LOOKING AT OWN HAND	When the participant seemed to be looking at own hands, whilst playing or touching the digital piano.
LOOKING AT THE OTHER PARTICIPANT'S HAND	When the participant seemed to be looking at the other participant's hands, for example when teacher used to look at student's hands whilst student was playing or vice versa.
MANIPULATING THE TECHNOLOGY	Operating the technology by opening and saving a project, zooming in or out the computer screen, or manipulating when looking for a specific section of the piano piece before playing it back.
OTHER NON-VERBAL BEHAVIOUR	Behaving with laughter, smiling, shaking head, nodding.
PLAYING	Performing the whole piano piece, or any moment for playing excerpts of the piano piece.
PLAYING BACK	Playing back the recording of the performance as requested by the teacher or the student, or suggested by the researcher (post-hoc feedback).
POINTING TO THE SCREEN	Pointing (deictic gesture) to the computer screen when they relate to any aspect for the technology-mediated feedback or they want to call the attention for a specific section of the piano piece.
POINTING TO THE SCORE	Pointing to the musical score when they relate to any aspect for the music score or they want to call attention of a specific section of the piano piece.
RECORDING	Recording whilst student or teacher or both were playing the piano piece (real-time feedback).
SILENT PLAYBACK	Operating the technology by moving computer screen or by keeping the frozen computer screen with a purpose (silent post-hoc feedback)
SINGING OR HUMMING	When participants used to sing or hum a specific section of the piano piece.
SPATIAL MOVEMENT	Any space that the participants take other than their original position for example: out of reach of the camera, moving, swapping the place with the other participant, standing in front of the computer screen, sitting on student's piano bench, sitting on teacher's chair.
TOUCHING	When teacher seemed to be touching their own hand, touching student's back, hand, arm, shoulder, or writ, and touching the bottoms of the digital piano.

Key: This table shows the list of 17 sub-categories of non-verbal behaviours (including feedback) which were related to the participants (teacher, student, and researcher) across case studies.

Table of sub-categories of non-verbal behaviours in case study A, lesson 1 and lesson 2

Teacher's *non-verbal* behaviours including feedback	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
T NV LOOKING AT THE COMPUTER SCREEN	385	35.36%	324	33.56%
T NV LOOKING AT THE MUSICAL SCORE	286	24.72%	263	26.92%
T NV SPATIAL MOVEMENT	57	5.55%	26	3.06%
T NV BODY AND HEAD MOVEMENTS	30	3.61%	48	10.03%
T NV POINTING TO THE MUSICAL SCORE	37	2.96%	23	2.12%
T NV HOLDING SCORE FOR STUDENT	30	2.39%	20	0.86%
T NV POINTING TO THE COMPUTER SCREEN	30	1.94%	35	2.80%
T NV OTHER NON-VERBAL BEHAVIOURS	54	1.92%	53	2.82%
T NV LOOKING AT STUDENT'S HANDS	22	1.65%	22	1.40%
T NV PLAYING	18	0.93%	24	1.78%
T NV LOOKING AT OWN HANDS	8	0.67%	5	0.38%
T NV SINGING OR HUMMING	3	0.36%	12	1.19%
T NV GESTURES	1	0.13%	22	1.73%
T NV TOUCHING	0	0.00%	20	0.95%
T NV USE OF METRONOME	0	0.00%	127	8.78%
sum	961	82.18%	1024	98.37%

Student's *non-verbal* behaviours including feedback	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
S LOOKING AT THE COMPUTER SCREEN	538	44.71%	512	46.39%
S NV PLAYING	141	14.62%	189	23.10%
S LOOKING AT THE MUSICAL SCORE	170	12.38%	95	9.17%
S LOOKING AT OWN HANDS	102	12.29%	128	14.50%
S NV SPATIAL MOVEMENT	70	6.08%	23	3.02%
S NV OTHER NON-VERBAL FEEDBACK	98	5.70%	92	5.48%
S NV GESTURES	56	5.36%	19	1.14%
S POINTING TO THE COMPUTER SCREEN	48	2.65%	10	0.82%
S NV SINGING	18	1.37%	4	0.48%
S POINTING TO THE MUSICAL SCORE	18	1.10%	1	0.09%
S LOOKING AT TEACHER'S HANDS	9	0.71%	12	0.84%
S NV BODY AND HEAD MOVEMENTS	3	0.29%	1	0.20%
S NV TOUCHING	6	0.22%	13	0.76%
sum	1277	107.48%	1099	105.98%

Researcher's *non-verbal* behaviours including feedback	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
R NV PLAYING BACK	109	15.57%	61	15.52%
R NV RECORDING	98	11.22%	158	20.44%
R NV MANIPULATING TECHNOLOGY	125	10.32%	128	8.63%
R NV MOVING OR FROZEN COMPUTER SCREEN	50	4.30%	2	6.09%
R NV SPATIAL MOVEMENT	52	3.09%	9	1.74%
R NV OTHER NON-VERBAL BEHAVIOUR	21	1.15%	9	0.96%
R NV POINTING	5	0.38%	0	0.00%
R NV SINGING	1	0.06%	0	0.00%
sum	461	46.10%	367	53.38%

Key: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed non-verbal behaviours in lesson 1 (4420 seconds) and in lesson 2 (3831 seconds), when using a CAQDA software NVivo10.

Table of sub-categories of non-verbal behaviours in case study B, lesson 1 and lesson 2

Teacher's *non-verbal* behaviours including feedback	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
T NV LOOKING AT THE MUSICAL SCORE	218	31.16%	136	14.36%
T NV LOOKING AT THE COMPUTER SCREEN	184	17.49%	349	43.73%
T NV BODY AND HEAD MOVEMENTS	35	9.06%	23	5.45%
T NV LOOKING AT STUDENT'S HANDS	102	8.62%	72	7.47%
T NV GESTURES	134	8.01%	92	7.36%
T NV SPATIAL MOVEMENT	54	7.32%	84	7.87%
T NV OTHER NON VERBAL FEEDBACK	97	6.97%	113	7.16%
T NV SINGING OR HUMMING	38	3.20%	21	1.84%
T NV LOOKING AT OWN HANDS	27	2.26%	26	2.36%
T NV WRITING ON THE SCORE	7	1.67%	9	2.55%
T NV POINTING TO THE SCORE	15	1.31%	10	0.80%
T NV PLAYING	14	1.29%	5	0.53%
T NV HOLDING SCORE FOR STUDENT	15	1.15%	0	0.00%
T NV POINTING TO THE COMPUTER SCREEN	19	1.08%	28	2.05%
T NV TOUCHING	3	0.26%	2	0.15%
sum	962	100.86%	970	103.68%

Student's *non-verbal* behaviours including feedback	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
S NV PLAYING	379	45.31%	324	39.68%
S LOOKING AT OWN HANDS	310	39.86%	264	33.98%
S LOOKING AT THE COMPUTER SCREEN	174	14.38%	311	34.23%
S NV SPATIAL MOVEMENT	100	11.78%	80	6.72%
S LOOKING AT THE MUSICAL SCORE	35	4.00%	56	4.99%
S NV OTHER NON-VERBAL BEHAVIOURS	40	2.90%	57	3.76%
S LOOKING AT TEACHER'S HANDS	16	1.61%	10	0.82%
S NV TOUCHING	12	1.06%	8	0.60%
S NV GESTURES	2	0.28%	5	0.55%
S NV SINGING	2	0.17%	0	0.00%
S POINTING TO THE COMPUTER SCREEN	2	0.11%	15	0.94%
S POINTING TO THE MUSICAL SCORE	0	0.00%	3	0.24%
sum	1072	121.48%	1133	126.51%

Researcher's *non-verbal* behaviours including feedback	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
R NV RECORDING	301	37.70%	174	25.21%
R NV MANIPULATING TECHNOLOGY	99	8.51%	130	12.88%
R NV PLAYING BACK	95	8.34%	84	12.37%
R NV SPATIAL MOVEMENT	46	6.76%	74	6.16%
R NV OTHER NON VERBAL BEHAVIOURS	14	0.91%	12	0.75%
SUM	555	62.21%	474	57.37%

Key: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed non-verbal behaviours in lesson 1 (2951 seconds) and in lesson 2 (2677 seconds), when using a CAQDA software NVivo10.

Table of sub-categories of non-verbal behaviours in case study C, lesson 1 and lesson 2

Teacher's *non-verbal* behaviours including feedback	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
T NV LOOKING AT THE MUSICAL SCORE	230	21.71%	200	18.92%
T NV SPATIAL MOVEMENT	68	20.23%	37	12.65%
T NV PLAYING	325	15.97%	406	20.82%
T NV LOOKING AT THE COMPUTER SCREEN	108	15.58%	106	17.37%
T NV LOOKING AT STUDENT'S HANDS	109	15.45%	247	25.16%
T NV LOOKING AT OWN HANDS	102	8.29%	142	12.09%
T NV BODY AND HEAD MOVEMENTS	59	5.22%	36	2.83%
T NV POINTING TO THE MUSIC SCORE	57	5.05%	33	3.12%
T NV GESTURES	59	4.37%	13	0.67%
T NV SINGING OR HUMMING	34	3.05%	22	2.12%
T NV OTHER NON-VERBAL BEHAVIOURS	33	1.86%	21	0.87%
T NV HOLDING MUSIC SCORE FOR STUDENT	13	1.42%	5	0.55%
T NV TOUCHING	9	0.62%	13	1.07%
T NV WRITING ON THE MUSIC SCORE	2	0.40%	13	1.18%
T NV POINTING TO THE COMPUTER SCREEN	4	0.23%	9	0.59%
sum	1212	119.44%	1303	120.01%

Student's *non-verbal* behaviours including feedback	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
S LOOKING AT OWN HANDS	128	26.50%	265	33.33%
S NV PLAYING	115	25.89%	181	29.66%
S NV SPATIAL MOVEMENT	49	18.44%	37	13.38%
S LOOKING AT THE COMPUTER SCREEN	114	16.01%	131	20.07%
S LOOKING AT THE MUSICAL SCORE	162	13.69%	146	12.98%
S LOOKING AT TEACHER'S HANDS	157	12.93%	210	18.16%
S NV OTHER NON-VERBAL BEHAVIOURS	76	5.32%	68	4.52%
S NV GESTURES	16	2.96%	2	0.25%
S NV BODY AND HEAD MOVEMENTS	9	0.82%	2	0.21%
S POINTING TO THE COMPUTER SCREEN	6	0.41%	3	0.24%
S NV TOUCHING	3	0.29%	3	0.25%
S POINTING TO THE MUSICAL SCORE	2	0.15%	2	0.13%
S NV SINGING	1	0.08%	0	0.00%
sum	838	123.50%	1050	133.19%

Researcher's *non-verbal* behaviours including feedback	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
R NV RECORDING	238	37.67%	271	38.94%
R NV MANIPULATING	111	10.40%	88	11.03%
R NV PLAYING BACK	55	8.40%	62	10.08%
R NV SPATIAL MOVEMENT	56	5.12%	13	1.57%
R NV OTHER NON-VERBAL BEHAVIOURS	9	0.64%	3	0.21%
R NV POINTING	3	0.30%	1	0.05%
R NV GESTURES	1	0.17%	0	0.00%
R NV SINGING	1	0.08%	0	0.00%
sum	474	62.79%	438	61.87%

Key: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed non-verbal behaviours in lesson 1 (2957 seconds) and in lesson 2 (3145 seconds), when using a CAQDA software NVivo10.

Appendix 9: Meta-category of musical performance parameters in this study

Number	Musical plus other parameters
1	Digital camera
2	Digital piano
3	Digital voice recorder
4	MIDI parameters
5	MIDI recording version
6	Articulation
7	Dynamics
8	Fingering
9	Harmony & Tonality
10	Melodic Accuracy
11	Metaphors
12	Motor control issues
13	Musical Structure
14	Other parameters such as attention, intention, consciousness, expression
15	Pedalling
16	Phrasing
17	Rhythmic Accuracy
18	Style
19	Technique
20	Tempo
21	Touch

Key: This table shows the list of 21 sub-categories of musical performance parameters which were observed in both lessons across case studies.

Table of sub-categories of musical performance parameters in case study A, lesson 1 and lesson 2

MUSICAL PLUS OTHER PARAMETERS	Case study A lesson 1		Case study A lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
MIDI parameters	254	15.16%	156	10.51%
Musical Structure	156	12.35%	67	4.80%
Pedalling	50	5.98%	0	0.00%
Tempo	36	4.10%	90	21.15%
Rhythmic Accuracy	47	4.04%	16	0.98%
Articulation	36	2.40%	9	0.73%
Digital piano	20	1.69%	0	0.00%
Phrasing	16	1.56%	26	3.23%
Harmony & Tonality	20	1.41%	20	2.03%
MIDI recording version	25	1.41%	28	1.94%
Motor control issues	21	1.37%	25	1.39%
Dynamics	13	1.00%	18	1.48%
Style	5	0.57%	2	0.32%
Other parameters	7	0.53%	10	0.67%
Metaphors	3	0.37%	12	1.26%
Technique	5	0.34%	62	5.06%
Touch	1	0.13%	0	0.00%
Digital camera	2	0.05%	0	0.00%
Melodic Accuracy	1	0.03%	1	0.03%
Fingering	0	0.00%	3	0.12%

Key1: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed musical performance parameters in lesson 1 (4420 seconds) and in lesson 2 (3831 seconds), when using a CAQDA software NVivo10.

Key2: There were observed 20 musical performance parameters from the list of 21 as shown in the table above.

Table of sub-categories of musical performance parameters in case study B, lesson 1 and lesson 2

MUSICAL PLUS OTHER PARAMETERS	Case study B lesson 1		Case study B lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
Tempo	77	13,49%	55	7.99%
Musical Structure	85	7.87%	72	5.66%
Phrasing	93	4.87%	4	0.54%
MIDI parameters	66	4.54%	123	8.54%
Articulation	52	2.87%	21	1.52%
Technique	36	2.62%	12	0.86%
Metaphors	19	1.70%	1	0.02%
Motor control issues	24	1.68%	95	7.06%
Fingering	12	1.46%	16	1.06%
MIDI recording version	14	1.12%	16	1.52%
Harmony & Tonality	10	1.11%	0	0.00%
Other parameters	11	1.03%	4	0.45%
Rhythmic Accuracy	10	0.68%	14	0.94%
Dynamics	9	0.30%	19	1.13%
Pedalling	3	0.26%	9	0.90%
Melodic Accuracy	3	0.25%	4	0.27%
Touch	1	0.19%	0	0.00%
Style	0	0.00%	2	0.10%

Key1: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed musical performance parameters in lesson 1 (2951 seconds) and in lesson 2 (2677 seconds), when using a CAQDA software NVivo10.

Key2: There were observed 18 musical performance parameters from the list of 21 as shown in the table above.

Table of sub-categories of musical performance parameters in case study C, lesson 1 and lesson 2

MUSICAL PLUS OTHER PARAMETERS	Case study C lesson 1		Case study C lesson 2	
	REFERENCES	COVERAGE (%)	REFERENCES	COVERAGE (%)
Tempo	167	13.67%	80	6.44%
Musical Structure	157	9.93%	155	11.01%
Rhythmic Accuracy	59	4.44%	38	2.53%
Dynamics	42	4.05%	38	3.87%
MIDI parameters	40	3.82%	43	2.74%
Motor control issues	40	3.50%	54	3.93%
Articulation	27	2.48%	78	5.88%
Metaphors	25	2.29%	13	1.03%
Technique	24	2.17%	44	2.89%
Phrasing	25	2.16%	26	2.32%
Digital piano	17	1.51%	2	0.18%
MIDI recording version	19	1.48%	27	1.94%
Touch	18	1.26%	2	0.13%
Style	16	1.20%	0	0.00%
Harmony & Tonality	9	0.87%	6	0.75%
Pedalling	6	0.74%	0	0.00%
Digital voice recorder	6	0.42%	0	0.00%
Melodic Accuracy	5	0.41%	19	1.35%
Other parameters	3	0.28%	10	0.79%
Fingering	0	0.00%	4	0.18%

Key1: This table shows the raw data (number of references and time coverage in percentage) of video QDA for observed musical performance parameters in lesson 1 (2957 seconds) and in lesson 2 (3145 seconds), when using a CAQDA software NVivo10

There were observed 20 musical plus other parameters from the list of 21 as shown in the table below.

Appendix 10: Cross-tabulation process for verbal and non-verbal feedback on musical performance parameters

A cross tabulation between behaviours (verbal and non-verbal) and musical performance parameters was conducted in CAQDA software NVivo10 where the matrices were run. The cross-tabulation seemed to reveal the types of verbal and non-verbal feedback per participant and related to musical performance parameters, namely music, performance and technology, which were worked on in the piano lessons per case study. The 15 most intercepted non-verbal and verbal behaviours linked to the musical performance parameters were investigated. A matrix coding query analysis was done primarily of a number of references intercepted between verbal (or non-verbal) behaviour and musical performance parameters. Subsequently, the respective coverage (percentage) for each type of feedback was found. Then, the 15 most observed types of feedback were grouped into three main sub-categories: music, performance and technology. Several types of feedback were discarded: those related to the researcher, use of metronome, or metaphor use.

The graphs (time bar charts) in chapter 6 (Video QDA: Verbal and non-verbal feedback across case studies) were built by calculating the time in seconds of each feedback type, and then the proportion of time spent in the total lesson time. The reference bar charts were built by calculating the percentage related to the total number of references for type of feedback. The matrix analysis might have revealed the types of verbal and non-verbal feedback which were available in lessons, even if they were not consciously delivered.

Table showing the cross tabulation process of observed verbal behaviours and musical performance parameters in case study A (both lessons) through the Excel spread sheet generated in CAQDA software NVivo10 by using matrix query tool

CASE STUDY A CROSSTABULATION BETWEEN VERBAL BEHAVIOURS AND MUSICAL PERFORMANCE PARAMETERS	A : CAMERA	B : DIGITAL PIANO	C : DIGITAL VOICE RECORDER	D : MIDI PARAMETERS	E : MIDI_recording version	F : TOUCH (TONE QUALITY OR SONORITY)	G : DYNAMICS	H : METAPHOR USE	I : MUSIC STRUCTURE	J : OTHER (ATTENTION EMOTIONAL EXPRESSIVITY MEMORY INTENTION CONSCIO	K : HARMONY AND TONALITY	L : MELODIC ACCURACY	M :STYLE	N : PHRASING	O : ARTICULATION	P : FINGERING	Q : PEDALLING	R : MOTOR CONTROL ISSUES (BODY POSITION BENCH POSITION ETC)	S : TECHNIQUE	T : RHYTHMIC ACCURACY	U : TEMPO	SUM
1 : R V ANSWERING (T or S)	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2 : R V ASKING QUESTIONS (to T or to S)	0	0	0	9	7	0	1	0	3	0	0	0	0	0	0	0	0	0	2	1	0	23
3 : R V BACKCHANELLING (yeah, yes, uhum, okay etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 : R V FEEDBACK OR PROVIDING INFORMATION (project, technolo	0	0	0	35	6	0	2	0	1	0	0	0	0	0	0	0	2	0	3	0	1	50
5 : R V GIVING DIRECTION (general to S to T or saying what R is goin	0	0	0	6	6	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	15
6 : R V OFF TASK (chatting or arranging time and day for interview etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 : R V OTHER BEHAVIOURS THAN FB (apologising thanking)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 : S V ANSWERING (T or R)	0	0	0	4	2	0	0	0	7	0	0	0	0	1	0	0	0	2	1	0	3	20
9 : S V ASKING QUESTIONS (to T or R)	0	0	0	6	4	0	0	0	7	0	0	0	0	1	0	0	4	0	2	0	0	24
10 : S V BACKCHANELLING (uhum, yes, yeah, ok)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
11 : S V COMENTING ON PREVIOUS EXPERIENCES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
12 : S V EMOTIONAL RESPONSES (all positive negative anxiety)	2	0	0	7	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	11
13 : S V FEEDBACK (providing info on what they see AND self evaluati	0	7	0	74	1	1	13	1	25	6	1	0	0	1	9	2	6	1	4	7	4	163
14 : S V GIVING DIRECTIONS (to T or R)	0	0	0	9	4	0	0	0	4	0	0	0	0	0	0	0	2	0	1	0	9	29
15 : S V OFF TASK (chatting or arranging for interview)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 : S V OTHER BEHAVIOURS THAN FEEDBACK (agreeing disagreei	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
17 : T V ANSWERING (S or R)	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	6
18 : T V ASKING QUESTIONS (to S or R or checking info)	0	2	0	23	6	0	1	0	14	2	0	0	0	0	1	0	1	4	4	2	3	63
19 : T V BACKCHANNELLING	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
20 : T V COMMENTING ON PREVIOUS EXPERIENCES	0	0	0	1	0	0	2	7	2	0	0	0	1	3	0	0	0	0	0	1	0	17
21 : T V EMOTIONAL RESPONSES (technology and technical difficulty	0	1	0	10	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	2	0	15
22 : T V GENERAL FEEDBACK (positive negative ambiguous)	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	3
23 : T V GIVING DIRECTIONS (to S or to R)	0	0	0	17	14	0	2	0	20	3	1	2	0	5	0	1	4	0	7	2	6	84
24 : T V OFF TASK (chatting or asking chair position or arranging interv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 : T V OTHER BEHAVIOURS THAN FB	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
26 : T V PLANNING SECOND SESSION (discussing the lesson focus f	0	0	0	2	0	0	1	0	3	0	0	0	0	2	2	0	2	0	1	2	0	15
27 : T V PROVIDING INFORMATION - FEEDBACK (providing informatio	0	8	0	84	2	0	6	7	107	4	26	0	6	28	18	0	24	8	20	30	6	384
SUM	2	20	0	295	54	1	30	15	198	16	28	2	7	41	30	3	48	16	48	47	33	934

Table showing the cross tabulation process of observed non-verbal behaviours and musical performance parameters in case study A (both lessons) through the Excel spread sheet generated in CAQDA software NVivo10 by using matrix query tool

CASE STUDY A CROSSTABULATION BETWEEN NON-VERBAL BEHAVIOURS AND MUSICAL PERFORMANCE PARAMETERS	A : CAMERA	B : DIGITAL PIANO	C : DIGITAL VOICE RECORDER	D : MIDI parameters	E : MIDI_recording version	F : TOUCH (TONE QUALITY OR SONORITY)	G : DYNAMICS	H : METAPHOR USE	I : MUSIC STRUCTURE	J : OTHER (ATTENTION, EMOTIONAL EXPRESSIVITY, MEMORY, INTENTION, CONSCIOUSNESS)	K : HARMONY AND TONALITY	L : MELODIC ACCURACY	M : STYLE	N : PHRASING	O : ARTICULATION	P : FINGERING	Q : PEDALLING	R : MOTOR CONTROL ISSUES (BODY POSITION BENCH POSITION ETC)	S : TECHNIQUE	T : RHYTHMIC ACCURACY	U : TEMPO	SUM
1 : R NV GESTURES (airplaying etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 : R NV OTHER NON VERBAL FB (laughter smiling nodding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 : R NV POINTING (pointing to the screen with arrow)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 : R NV SINGING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 : R NV SPATIAL MOVEMENT (moving and out of the reach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 : R NV Technology mediated SILENT POST HOC FB (MOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 : R NV Technology mediation MANIPULATING the technog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 : R NV Technology mediation PLAYING BACK (ORIGINAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
9 : R NV Technology mediation RECORDING performances (	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 : S NV BODY AND HEAD MOVEMENTS (bouncing the bo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
11 : S NV GESTURES (SILENT WITH SOUND AND AIR AND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	6	13
12 : S NV looking at own hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 : S NV looking at T hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 : S NV looking at the score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 : S NV looking at the screen (real time and post hoc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 : S NV OTHER NON VERBAL FEEDBACK (smiling laugh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 : S NV PLAYING (all)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	7
18 : S NV pointing to the score	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
19 : S NV pointing to the screen	0	0	0	29	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	30
20 : S NV SINGING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 : S NV SPATIAL MOVEMENT (all)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 : S NV TOUCHING (keyboard, digital piano, piano stool, ov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	6
23 : T NV BODY AND HEAD MOVEMENTS (bouncing body	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	66
24 : T NV GESTURES (SILENT WITH SOUND AIR AND MUT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	9	0	6	26
25 : T NV HOLDING SCORE FOR S	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
26 : T NV looking at own hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 : T NV looking at S hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
28 : T NV looking at the computer screen (all playback and re	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29 : T NV looking at the musical score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
30 : T NV OTHER NON VERBAL FEEDBACK (smiling laugh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31 : T NV PLAYING	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	11
32 : T NV pointing to the score	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	23
33 : T NV pointing to the screen	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
34 : T NV SINGING (and humming)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35 : T NV SPATIAL MOVEMENT (T to S place and back to T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36 : T NV TECHNOLOGY METRONOME ON (TRANSCRIPT)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	127
37 : T NV TOUCHING (student digital piano or own hands)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38 : T NV WRITING DOWN (on score or comments on paper)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	0	0	63	0	0	0	0	26	0	11	0	0	0	7	0	1	24	9	0	212	353

Table showing the cross tabulation process of observed verbal behaviours and musical performance parameters in case study B (both lessons) through the Excel spread sheet generated in CAQDA software NVivo10 by using matrix query tool

CASE STUDY B CROSSTABULATION BETWEEN VERBAL BEHAVIOURS AND MUSICAL PERFORMANCE PARAMETERS	A : CAMERA	B : DIGITAL PIANO	C : DIGITAL VOICE RECORDER	D : MIDI PARAMETERS	E : MIDI_recording version	F : TOUCH (TONE QUALITY OR SONORITY)	G : DYNAMICS	H : METAPHOR USE	I : MUSIC STRUCTURE	J : OTHER (ATTENTION EMOTIONAL EXPRESSIVITY MEMORY INTENTION ON CONSCIOUSSNESS)	K : HARMONY AND TONALITY	L : MELODIC ACCURACY	M : STYLE	N : PHRASING	O : ARTICULATION	P : FINGERING	Q : PEDALLING	R : MOTOR CONTROL ISSUES (BODY POSITION BENCH POSITION ETC)	S : TECHNIQUE	T : RHYTHMIC ACCURACY	U : TEMPO	SUM
1 : R V ANSWERING (T or S)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 : R V ASKING QUESTIONS (to T or to S)	0	0	0	16	2	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	22
3 : R V BACKCHANELLING (yeah, yes, uhum, c	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
4 : R V FEEDBACK OR PROVIDING INFORMAT	0	0	0	3	2	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8
5 : R V GIVING DIRECTION (general to S to T or	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
6 : R V OFF TASK (chatting or arranging time ar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 : R V OTHER BEHAVIOURS THAN FB (apolog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 : S V ANSWERING (T or R)	0	1	0	0	1	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	6
9 : S V ASKING QUESTIONS (to T or R)	1	0	0	4	0	0	0	0	6	1	0	0	0	0	0	1	0	1	1	0	0	15
10 : S V BACKCHANELLING (uhum, yes, yeah,	0	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	9
11 : S V COMENTING ON PREVIOUS EXPERIE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 : S V EMOTIONAL RESPONSES (all positive	0	5	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8
13 : S V FEEDBACK (providing info on what they	0	6	0	17	0	0	1	1	12	4	0	0	0	1	1	6	0	7	3	6	7	72
14 : S V GIVING DIRECTIONS (to T or R)	0	0	0	6	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	10
15 : S V OFF TASK (chatting or arranging for int	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 : S V OTHER BEHAVIOURS THAN FEEDBA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 : T V ANSWERING (S or R)	0	1	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	7
18 : T V ASKING QUESTIONS (to S or R or che	0	3	0	2	0	0	0	0	1	0	0	0	0	2	1	0	0	0	2	0	0	11
19 : T V BACKCHANNELLING	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
20 : T V COMMENTING ON PREVIOUS EXPER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	3
21 : T V EMOTIONAL RESPONSES (technology	2	0	0	8	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	14
22 : T V GENERAL FEEDBACK (positive negati	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
23 : T V GIVING DIRECTIONS (to S or to R)	0	2	0	19	20	0	8	7	41	2	2	2	0	9	10	2	2	15	12	2	11	166
24 : T V OFF TASK (chatting or asking chair pos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 : T V OTHER BEHAVIOURS THAN FB	0	1	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6
26 : T V PLANNING SECOND SESSION (discus	0	0	0	0	0	0	0	1	1	0	0	0	0	2	3	2	0	0	0	0	0	9
27 : T V PROVIDING INFORMATION - FEEDBA	0	34	0	69	3	1	10	10	54	5	5	2	2	16	29	14	8	54	21	8	18	363
SUM	3	58	0	165	30	1	21	20	126	13	7	4	2	31	44	27	13	82	40	16	37	740

Table showing the cross tabulation process of observed non-verbal behaviours and musical performance parameters in case study B (both lessons) through the Excel spread sheet generated in CAQDA software NVivo10 by using matrix query tool

CASE STUDY B CROSSTABULATION BETWEEN NON-VERBAL BEHAVIOURS AND MUSICAL PERFORMANCE PARAMETERS	A : CAMERA	B : DIGITAL PIANO	C : DIGITAL VOICE RECORDER	D : MIDI_PARAMETERS	E : MIDI_recording version	F : TOUCH (TONE QUALITY OR SONORITY)	G : DYNAMICS	H : METAPHOR USE	I : MUSIC STRUCTURE	J : OTHER (ATTENTION EMOTIONAL EXPRESSIVITY MEMORY INTENTION CONSCIOUSSNESS)	K : HARMONY AND TONALITY	L : MELODIC ACCURACY	M : STYLE	N : PHRASING	O : ARTICULATION	P : FINGERING	Q : PEDALLING	R : MOTOR CONTROL ISSUES (BODY POSITION BENCH POSITION ETC)	S : TECHNIQUE	T : RHYTHMIC ACCURACY	U : TEMPO	SUM
1 : R NV GESTURES (airplaying etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 : R NV OTHER NON VERBAL FB (laughter smiling nodding s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 : R NV POINTING (pointing to the screen with arrow)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 : R NV SINGING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 : R NV SPATIAL MOVEMENT (moving and out of the reach o	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
6 : R NV Technology mediated SILENT POST HOC FB (MOVIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 : R NV Technology mediation MANIPULATING the technogy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 : R NV Technology mediation PLAYING BACK (ORIGINAL SL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 : R NV Technology mediation RECORDING performances (RE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
10 : S NV BODY AND HEAD MOVEMENTS (bouncing the bod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 : S NV GESTURES (SILENT WITH SOUND AND AIR AND M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
12 : S NV looking at own hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 : S NV looking at T hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 : S NV looking at the score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 : S NV looking at the screen (real time and post hoc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 : S NV OTHER NON VERBAL FEEDBACK (smiling laughter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 : S NV PLAYING (all)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
18 : S NV pointing to the score	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
19 : S NV pointing to the screen	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
20 : S NV SINGING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 : S NV SPATIAL MOVEMENT (all)	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
22 : S NV TOUCHING (keyboard, digital piano, piano stool, owr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 : T NV BODY AND HEAD MOVEMENTS (bouncing body an	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	58	67
24 : T NV GESTURES (SILENT WITH SOUND AIR AND MUTE	0	0	0	0	0	0	3	0	0	0	0	0	0	26	7	0	0	39	1	0	40	116
25 : T NV HOLDING SCORE FOR S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 : T NV looking at own hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 : T NV looking at S hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28 : T NV looking at the computer screen (all playback and real	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29 : T NV looking at the musical score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 : T NV OTHER NON VERBAL FEEDBACK (smiling laughter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31 : T NV PLAYING	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
32 : T NV pointing to the score	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	25
33 : T NV pointing to the screen	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
34 : T NV SINGING (and humming)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35 : T NV SPATIAL MOVEMENT (T to S place and back to T pl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36 : T NV TECHNOLOGY METRONOME ON (TRANSCRIPT)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37 : T NV TOUCHING (student digital piano or own hands)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38 : T NV WRITING DOWN (on score or comments on paper)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	6	0	24	0	0	3	0	28	0	3	0	0	35	7	0	0	42	1	0	98	247

Table showing the cross tabulation process of observed verbal behaviours and musical performance parameters in case study C (both lessons) through the Excel spread sheet generated in CAQDA software NVivo10 by using matrix query tool

CASE STUDY C CROSSTABULATION BETWEEN VERBAL BEHAVIOURS AND MUSICAL PERFORMANCE PARAMETERS	A : CAMERA	B : DIGITAL PIANO	C : DIGITAL VOICE RECORDER	D : MIDI_PARAMETERS	E : MIDI_recording version	F : TOUCH (TONE QUALITY OR SONORITY)	G : DYNAMICS	H : METAPHOR USE	I : MUSIC STRUCTURE	J : OTHER (ATTENTION EMOTIONAL EXPRESSIVITY MEMORY INTENTION CONSCIO	K : HARMONY AND TONALITY	L : MELODIC ACCURACY	M : STYLE	N : PHRASING	O : ARTICULATION	P : FINGERING	Q : PEDALLING	R : MOTOR CONTROL ISSUES (BODY POSITION BENCH POSITION ETC)	S : TECHNIQUE	T : RHYTHMIC ACCURACY	U : TEMPO	SUM
1 : R V ANSWERING (T or S)	0	0	0	4	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8
2 : R V ASKING QUESTIONS (to T or to S)	0	0	0	14	13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	28
3 : R V BACKCHANELLING (yeah, yes, uhum, okay etc)	0	1	0	4	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	14
4 : R V FEEDBACK OR PROVIDING INFORMATION (project, technolog	0	1	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8
5 : R V GIVING DIRECTION (general to S to T or saying what R is going	0	0	1	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
6 : R V OFF TASK (chatting or arranging time and day for interview etc)	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
7 : R V OTHER BEHAVIOURS THAN FB (apologising thanking)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 : S V ANSWERING (T or R)	0	1	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	3	2	11
9 : S V ASKING QUESTIONS (to T or R)	0	0	0	1	0	0	1	0	6	0	0	4	0	0	0	0	0	0	0	0	0	12
10 : S V BACKCHANELLING (uhum, yes, yeah, ok)	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	2	2	12
11 : S V COMENTING ON PREVIOUS EXPERIENCES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 : S V EMOTIONAL RESPONSES (all positive negative anxiety)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 : S V FEEDBACK (providing info on what they see AND self evaluatio	0	0	0	5	0	0	1	1	7	0	0	0	0	2	0	0	0	1	2	3	2	24
14 : S V GIVING DIRECTIONS (to T or R)	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
15 : S V OFF TASK (chatting or arranging for interview)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 : S V OTHER BEHAVIOURS THAN FEEDBACK (agreeing disagreein	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
17 : T V ANSWERING (S or R)	0	0	0	6	8	0	0	1	7	0	0	1	0	0	0	0	0	0	1	0	0	24
18 : T V ASKING QUESTIONS (to S or R or checking info)	0	1	0	6	8	0	0	1	10	5	0	1	1	0	2	1	0	2	5	4	2	49
19 : T V BACKCHANNELLING	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
20 : T V COMMENTING ON PREVIOUS EXPERIENCES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 : T V EMOTIONAL RESPONSES (technology and technical difficulty)	0	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	1	8
22 : T V GENERAL FEEDBACK (positive negative ambiguous)	0	0	0	0	2	3	2	2	3	0	0	1	0	2	0	1	0	1	0	2	1	20
23 : T V GIVING DIRECTIONS (to S or to R)	0	1	0	27	26	7	24	7	83	2	1	5	1	15	12	2	3	28	12	20	64	340
24 : T V OFF TASK (chatting or asking chair position or arranging intervie	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
25 : T V OTHER BEHAVIOURS THAN FB	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	2
26 : T V PLANNING SECOND SESSION (discussing the lesson focus fo	0	1	0	0	0	0	0	0	2	0	0	1	0	0	4	0	0	2	1	5	0	16
27 : T V PROVIDING INFORMATION - FEEDBACK (providing information	0	13	0	14	1	9	52	26	91	4	11	12	9	31	28	1	3	40	22	27	18	412
SUM	0	22	6	108	72	19	81	38	217	11	12	27	11	50	46	5	7	75	48	69	92	1016

Table showing the cross tabulation process of observed non-verbal behaviours and musical performance parameters in case study C (both lessons) through the Excel spread sheet generated in CAQDA software NVivo10 by using matrix query tool

CASE STUDY C CROSSTABULATION BETWEEN NON-VERBAL BEHAVIOURS AND MUSICAL PERFORMANCE PARAMETERS	A : CAMERA	B : DIGITAL PIANO	C : DIGITAL VOICE RECORDER	D : MIDI_ PARAMETERS	E : MIDI_recording version	F : TOUCH (TONE QUALITY OR SONORITY)	G : DYNAMICS	H : METAPHOR USE	I : MUSIC STRUCTURE	J : OTHER (ATTENTION EMOTIONAL EXPRESSIVITY MEMORY INTENTION CONSCIO	K : HARMONY AND TONALITY	L : MELODIC ACCURACY	M : STYLE	N : PHRASING	O : ARTICULATION	P : FINGERING	Q : PEDALLING	R : MOTOR CONTROL ISSUES (BODY POSITION BENCH POSITION ETC)	S : TECHNIQUE	T : RHYTHMIC ACCURACY	U : TEMPO	SUM
1 : R NV GESTURES (airplaying etc)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 : R NV OTHER NON VERBAL FB (laughter smiling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 : R NV POINTING (pointing to the screen with arrow	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4 : R NV SINGING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 : R NV SPATIAL MOVEMENT (moving and out of t	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 : R NV Technology mediated SILENT POST HOC F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 : R NV Technology mediation MANIPULATING the	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 : R NV Technology mediation PLAYING BACK (OF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
9 : R NV Technology mediation RECORDING perform	0	0	0	0	0	0	0	0	1	0	5	0	0	0	46	0	0	0	3	3	9	67
10 : S NV BODY AND HEAD MOVEMENTS (bounci	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11
11 : S NV GESTURES (SILENT WITH SOUND AND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	15
12 : S NV looking at own hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 : S NV looking at T hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
14 : S NV looking at the score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 : S NV looking at the screen (real time and post h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
16 : S NV OTHER NON VERBAL FEEDBACK (smili	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 : S NV PLAYING (all)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	24	0	0	0	0	0	4	29
18 : S NV pointing to the score	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4
19 : S NV pointing to the screen	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
20 : S NV SINGING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 : S NV SPATIAL MOVEMENT (all)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
22 : S NV TOUCHING (keyboard, digital piano, piano	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 : T NV BODY AND HEAD MOVEMENTS (bouncir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	70	72
24 : T NV GESTURES (SILENT WITH SOUND AIR A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	34	40
25 : T NV HOLDING SCORE FOR S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 : T NV looking at own hands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
27 : T NV looking at S hands	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
28 : T NV looking at the computer screen (all playbac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
29 : T NV looking at the musical score	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2
30 : T NV OTHER NON VERBAL FEEDBACK (smilir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31 : T NV PLAYING	0	0	0	0	0	0	0	0	0	0	5	0	4	0	31	0	0	2	9	3	7	61
32 : T NV pointing to the score	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	0	0	0	0	88
33 : T NV pointing to the screen	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
34 : T NV SINGING (and humming)	0	0	0	0	0	0	0	0	4	0	0	0	0	3	0	0	0	0	0	8	2	17
35 : T NV SPATIAL MOVEMENT (T to S place and b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36 : T NV TECHNOLOGY METRONOME ON (TRANS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37 : T NV TOUCHING (student digital piano or own ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	14
38 : T NV WRITING DOWN (on score or comments c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	0	0	0	5	0	0	0	0	100	0	10	0	4	3	102	0	0	19	15	21	156	435

Table showing the 15 most observed types of verbal feedback on musical performance parameters in case study A

Types of verbal feedback for case study A	Lesson 1 references	Lesson 1 coverage (%)	Lesson 2 references	Lesson 2 coverage (%)	Sum of references	Sum of coverage (%)	Reference ranking	Coverage ranking
Teacher providing information on music structure	78	7.00	29	3.19	107	10.19	1	1
Teacher providing information on MIDI parameters	41	3.30	43	4.56	84	7.86	2	2
Student providing information on MIDI parameters	46	2.87	28	2.08	74	4.95	3	3
Researcher providing information on MIDI parameters	26	2.13	9	0.68	35	2.81	4	7
Teacher providing information on rhythmic accuracy	25	2.59	5	0.73	30	3.32	5	5
Teacher providing information on phrasing	11	1.03	17	2.40	28	3.43	6	4
Teacher providing information on harmony and tonality	13	1.04	13	1.44	26	2.48	7	8
Student providing information on music structure	24	1.68	1	0.06	25	1.74	8	12
Teacher providing information on pedalling	24	3.03	0	0.00	24	3.03	9	6
Teacher asking questions on MIDI parameters	14	1.40	9	0.75	23	2.15	10	10
Teacher providing information on technique	2	0.14	18	2.07	20	2.21	11	9
Teacher giving directions on music structure	10	0.89	10	0.85	20	1.74	12	13
Teacher providing information on articulation	14	1.40	4	0.51	18	1.91	13	11
Teacher giving directions on MIDI parameters	16	0.93	1	0.14	17	1.07	14	14
Teacher giving directions on MIDI recording version	6	0.27	8	0.51	14	0.78	15	15

Table showing the 15 most observed types of non-verbal feedback on musical performance parameters in case study A

Types of non-verbal feedback in case study A	Lesson 1 references	Lesson 1 coverage (%)	Lesson 2 references	Lesson 2 coverage (%)	Sum of references	Sum of coverage (%)	Reference ranking	Coverage ranking
Teacher metronome use for tempo	0	0.00	127	8.78	127	8.78	1	2
Teacher body and head movements for tempo	18	3.61	48	10.03	66	13.64	2	1
Teacher pointing to the computer screen for MIDI parameters	15	0.74	19	1.69	34	2.43	3	3
Student pointing to the computer screen for MIDI parameters	23	1.35	6	0.37	29	1.72	4	5
Teacher pointing to the music score for music structure	0	0.00	23	2.12	23	2.12	5	4
Teacher gestures for motor control issues	0	0.00	11	0.83	11	0.83	6	7
Teacher playing for harmony and tonality	5	0.28	6	0.51	11	0.79	7	8
Teacher gestures for technique	0	0.00	9	0.76	9	0.76	8	9
Student gestures for motor control issues	5	1.07	2	0.07	7	1.14	9	6
Student playing for articulation	4	0.16	3	0.13	7	0.29	10	13
Student gestures for tempo	3	0.44	3	0.29	6	0.73	11	10
Teacher gestures for tempo	0	0.00	6	0.40	6	0.40	12	12
Student touching for motor control issues	6	0.22	0	0.00	6	0.22	13	14
Student body and head movement for tempo	3	0.29	1	0.2	4	0.49	14	11
Student pointing to the music score for music structure	0	0	1	0.09	1	0.09	15	15

Table showing the 15 most observed types of verbal feedback on musical performance parameters in case study B

Types of verbal feedback in case study B	Lesson 1 references	Lesson 1 coverage (%)	Lesson 2 references	Lesson 2 coverage (%)	Sum of references	Sum of coverage (%)	Reference ranking	Coverag e ranking
Teacher providing information on MIDI parameter	27	1.96	42	3.74	69	5.70	1	2
Teacher providing information on music structure	27	3.70	27	2.89	54	6.59	2	1
Teacher providing information on motor control issues	11	0.91	43	4.37	54	5.28	3	3
Teacher giving directions on music structure	23	1.85	18	1.73	41	3.58	4	5
Teacher providing information on digital piano	29	3.40	5	0.66	34	4.06	5	4
Teacher providing information on articulation	17	1.56	12	1.11	29	2.67	6	6
Teacher providing information on technique	14	1.29	7	0.55	21	1.84	7	8
Teacher giving directions on MIDI recording version	9	0.77	11	0.96	20	1.73	8	9
Teacher giving direction on MIDI parameters	11	0.80	8	0.61	19	1.41	9	11
Teacher providing information on tempo	14	1.60	4	0.40	18	2.00	10	7
Student providing information on MIDI parameters	1	0.03	16	1.05	17	1.08	11	13
Teacher providing information on phrasing	14	1.36	2	0.18	16	1.54	12	10
Researcher asking questions on MIDI parameters	8	0.54	8	0.43	16	0.97	13	14
Teacher giving directions on motor control	5	0.35	10	0.55	15	0.90	14	15
Teacher providing information on fingering	6	0.71	8	0.65	14	1.36	15	12

Table showing the 15 most observed types of non-verbal feedback on musical performance parameters in case study B

Types of non-verbal feedback in case study B	Lesson 1 references	Lesson 1 coverage (%)	Lesson 2 references	Lesson 2 coverage (%)	Sum of references	Sum of coverage (%)	Reference ranking	Coverage ranking
Teacher body and head movements for tempo	35	9.06	23	5.45	58	14.51	1	1
Teacher gestures for tempo	24	2.58	16	1.66	40	4.24	2	2
Teacher gestures for motor control issues	7	0.64	32	3.29	39	3.93	3	3
Teacher gestures for phrasing	24	1.68	2	0.36	26	2.04	4	5
Teacher pointing to the music score for music structure	15	1.31	10	0.80	25	2.11	5	4
Teacher pointing to the computer screen for MIDI parameters	5	0.31	15	1.25	20	1.56	6	6
Teacher head and body movement for phrasing	9	0.73	0	0.00	9	0.73	7	7
Teacher gestures for articulation	7	0.53	0	0.00	7	0.53	8	8
Student pointing to the computer screen for MIDI parameters	1	0.03	3	0.18	4	0.21	9	13
Teacher playing for harmony & tonality	3	0.31	0	0.00	3	0.31	10	9
Student spatial movement for digital piano	3	0.30	0	0.00	3	0.30	11	10
Researcher spatial movement for digital piano	3	0.30	0	0.00	3	0.30	12	11
Student pointing to the music score for music structure	0	0.00	3	0.24	3	0.24	13	12
Teacher gestures for dynamics	1	0.05	2	0.10	3	0.15	14	14
Teacher gestures for technique	1	0.06	0	0.00	1	0.06	15	15

Table showing the 15 most observed types of verbal feedback on musical performance parameters in case study C

Types of verbal feedback in case study C	Lesson 1 references	Lesson 1 coverage (%)	Lesson 2 references	Lesson 2 coverage (%)	Sum of references	Sum of coverage (%)	Reference ranking	Coverage ranking
Teacher providing information on music structure	39	3.53	52	5.25	91	8.78	1	1
Teacher giving directions on music structure	32	2.26	51	3.65	83	5.91	2	2
Teacher giving directions on tempo	39	3.07	25	2.18	64	5.25	3	3
Teacher providing information on dynamics	23	2.28	29	2.88	52	5.16	4	4
Teacher providing information on motor control issues	17	1.55	23	1.78	40	3.33	5	5
Teacher providing information on phrasing	11	1.12	20	1.99	31	3.11	6	6
Teacher providing information on articulation	15	1.64	13	1.24	28	2.88	7	7
Teacher giving directions on motor control issues	10	1.04	18	1.42	28	2.46	8	9
Teacher providing information on rhythmic accuracy	13	1.29	14	1.43	27	2.72	9	14
Teacher giving directions on MIDI parameters	8	0.58	19	1.42	27	2.00	10	11
Teacher providing information on metaphor use	20	1.93	6	0.62	26	2.55	11	8
Teacher giving directions on MIDI recording versions	12	0.82	14	0.93	26	1.75	12	13
Teacher giving directions on dynamics	16	1.46	8	0.84	24	2.30	13	10
Teacher providing information on technique	6	0.83	16	1.77	22	2.60	14	15
Teacher giving directions on rhythmic accuracy	17	1.57	3	0.19	20	1.76	15	12

Table showing the 15 most observed types of non-verbal feedback on musical performance parameters in case study C

Types of non-verbal feedback in case study C	Lesson 1 references	Lesson 1 coverage (%)	Lesson 2 references	Lesson 2 coverage (%)	Sum of references	Sum of coverage (%)	Reference ranking	Coverage ranking
Teacher pointing to the music score for music structure	56	4.98	32	3.02	88	8.00	1	2
Teacher body and head movement for tempo	49	5.22	21	2.83	70	8.05	2	1
Researcher recording for articulation	1	0.13	45	3.89	46	4.02	3	3
Teacher gestures for tempo	30	2.49	4	0.21	34	2.70	4	7
Teacher playing for articulation	2	0.20	29	2.09	31	2.29	5	4
Student playing for articulation	0	0.00	24	2.15	24	2.15	6	5
Student gestures for tempo	15	2.79	0	0.00	15	2.79	7	6
Teacher touching for motor control issues	5	0.34	9	0.83	14	1.17	8	8
Student body and head movement for tempo	9	0.82	2	0.21	11	1.03	9	9
Teacher playing for technique	9	0.73	0	0.00	9	0.73	10	12
Researcher recording for tempo	9	0.66	0	0.00	9	0.66	11	10
Teacher singing for rhythmic accuracy	8	0.77	0	0.00	8	0.77	12	15
Teacher playing for tempo	7	0.60	0	0.00	7	0.60	13	11
Teacher gestures for rhythmic accuracy	6	0.37	0	0.00	6	0.37	14	13
Teacher playing for harmony and tonality	4	0.45	1	0.26	5	0.71	15	14

Appendix 11: SYMP software details

Video QDA for microstructure analysis of musical behaviour (musical practice in terms of playing and listening back) by using Study Your Musical Performance (SYMP) software in Excel spread sheets designed by Demos & Chaffin (2009).

	A	B	C	D	E	F
1		**Please answer the question below.**				
2		**General Questions**				
3		What is the name of the music you are leaning?				
4		Piano Sonata k 545 2nd mov.				
5		Who is the composer?				
6		Mozart				
7		What edition of the score are you using?				
8						
9						
10		**Questions about the score**				
11		Does the meter of the music remain constant throught the movement/piece you are going to study?				
12		yes				
13		If yes enter the meter as follows (enter the meter you plan to use for your analyis)				
14		3	Top number			
15		4	Bottom number			
16						
17		If no, we suggest you ignore the bars and work in beats				
18		*Please see our instructions for more information on the topic of working in beat or bars.*				
19						
20						
21		Do you plan to work in beats or bars (or some multiple of bars).				
22		Enter 1 for beat and 2 for bars				
23		2				
24						
25						
26		**For those working in beats:**				
27		Please enter the total number of beats in the music				
28						
29						
30		**For those working in bars:**				
31		Please enter the total number of bars in the music				
32		74				
33						
34						
35						
36						
37						
38						
39						

Music Information | Journal | Practice Sessions | Cues | Practice Graph | Per Measure & Cue Type

Key: This figure shows SYMP music information Excel spread sheet for case study A lesson 1.

	B	C	D	E	F	G	H	I	J	N	O	P
1	Practice Sessions	Segment	Start Time on Video Tape (mins)	Start Time on Video Tape (seconds)	Amount of Time Talking (seconds)	Start Bar	Start Beat	Stop Bar	Stop Beat	Time Playing (seconds)	Number of measured played	
2	1	1	0	00		0	0	0	0	00	0.00	
3	1	2	7	10		1	1	47	3	326	46.00	
4	1	3	12	37		47	3	47	3	01	0.00	
5	1	4	12	39		48	1	48	1	01	0.00	
6	1	5	12	40		48	1	48	1	01	0.00	
7	1	6	12	42		48	1	48	1	01	0.00	
8	1	7	12	43		48	1	48	1	01	0.00	
9	1	8	12	45		48	1	71	1	36	23.00	
10	1	9	13	22		71	1	74	3	63	3.00	
11	1	10	15	53		1	1	2	1	06	1.00	playback
12	1	11	16	28		1	1	47	3	326	46.00	playback
13	1	12	21	56		47	3	47	3	01	0.00	playback
14	1	13	21	57		48	1	48	1	01	0.00	playback
15	1	14	21	59		48	1	48	1	01	0.00	playback
16	1	15	22	00		48	1	48	1	01	0.00	playback
17	1	16	22	01		48	1	48	1	01	0.00	playback
18	1	17	22	03		48	1	71	1	36	23.00	playback
19	1	18	22	41		71	1	74	3	63	3.00	playback
20	1	19	26	10		1	1	1	2	02	0.00	
21	1	20	26	12		1	1	1	3	03	0.00	
22	1	21	26	17		1	1	1	3	05	0.00	
23	1	22	26	22		1	1	1	3	02	0.00	
24	1	23	26	59		40	2	41	1	02	1.00	
25	1	24	27	04		40	2	41	1	08	1.00	
26	1	25	29	15		17	1	17	1	03	0.00	
27	1	26	29	18		17	1	18	3	03	1.00	
28	1	27	30	00		30	2	30	2	01	0.00	
29	1	28	30	1		30	3	31	2	02	1.00	
30	1	29	30	6		30	3	31	2	03	1.00	
31	1	30	30	50		35	1	35	2	01	0.00	
32	1	31	31	24		45	1	45	1	03	0.00	
33	1	32	31	29		45	1	45	1	01	0.00	
34	1	33	31	30		45	1	45	1	01	0.00	
35	1	34	31	31		45	1	45	1	01	0.00	
36	1	35	31	32		45	1	45	1	01	0.00	
37	1	36	31	39		43	1	46	1	15	3.00	playback
38	1	37	33	23		70	1	70	3	07	0.00	
39	1	38	37	34		15	3	16	3	03	1.00	playback
40	1	39	37	39		1	1	2	1	03	1.00	playback
41	1	40	38	12		14	2	16	1	11	2.00	playback

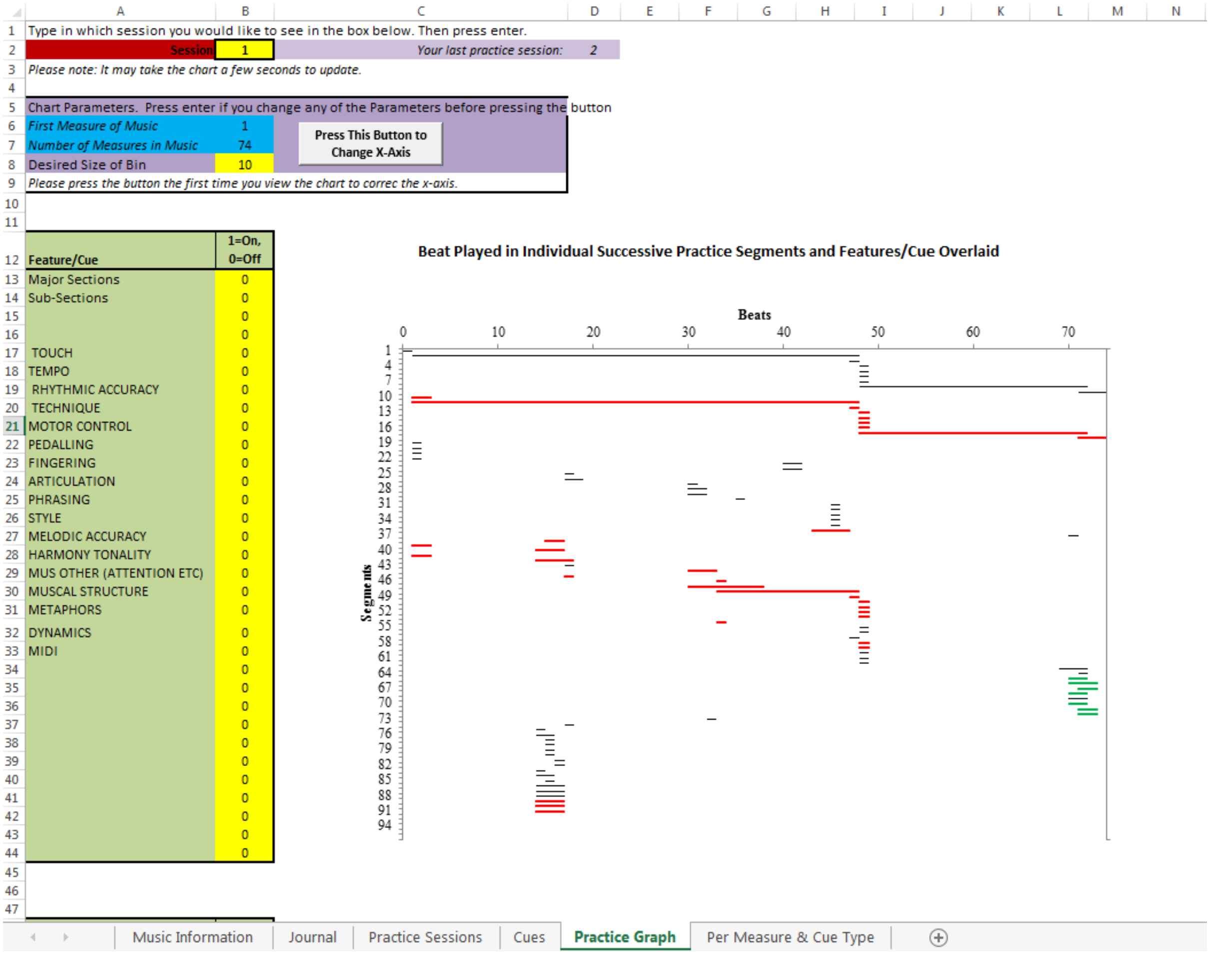
Music Information | Journal | **Practice Sessions** | Cues | Practice Graph | Per Measure & Cue Type

Key: This figure shows SYMP practice sessions SYMP music information Excel spread sheet for case study A lesson 1.

Bars	Major Sections	Sub-Sections			TOUCH	TEMPO	RHYTHMIC ACCURACY	TECHNIQUE	MOTOR CONTROL	PEDALLING	FINGERING	ARTICULATION	PHRASING	STYLE	MELODIC ACCURACY	HARMONY TONALITY	MUS OTHER (ATTENTION ETC)	MUSCAL STRUCTURE	METAPHORS	DYNAMICS	MIDI
1	1	1			0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1
2	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
3	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	1			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0			0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
15	0	0			0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
16	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	1	1			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
18	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	1			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
31	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
32	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
33	1	1			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
34	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
35	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
36	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
37	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
38	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
39	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
40	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
41	0	1			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
42	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
43	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
44	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
45	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
46	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
47	0	0			0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
48	0	0			0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1
49	1	1			0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
50	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Music Information | Journal | Practice Sessions | **Cues** | Practice Graph | Per Measure & Cue Type

Key: This figure shows SYMP practice sessions SYMP performance cues Excel spread sheet for case study A lesson 1.

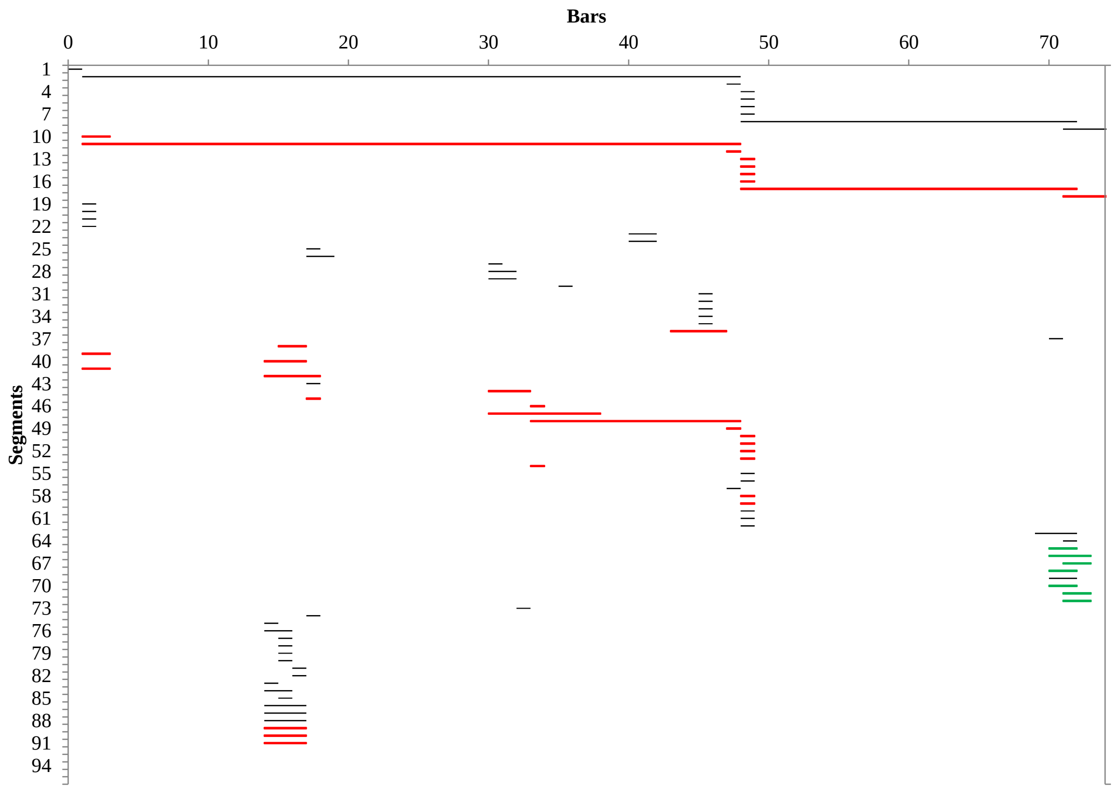


Key: This figure shows SYMP practice graph for musical behaviours (playing and listening back) Excel spread sheet for case study A lesson 1.

Appendix 12: Microstructure analysis of musical behaviours

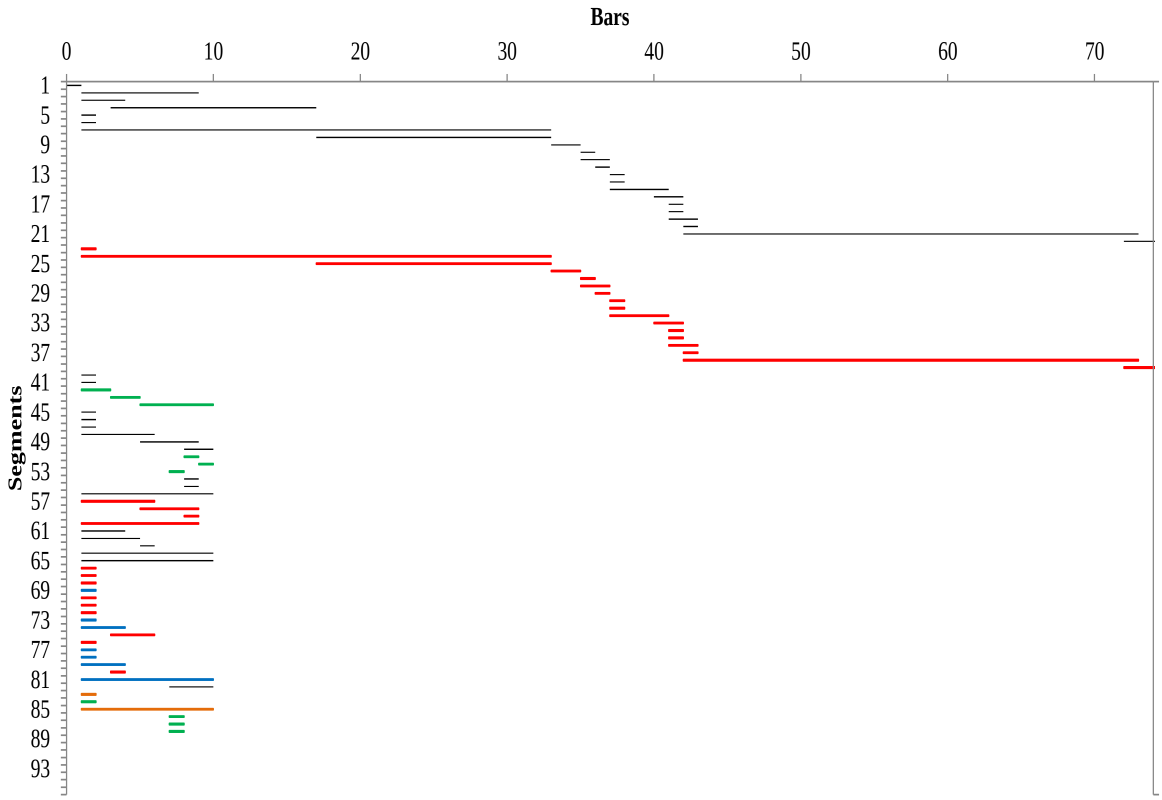
Graphs derived from the microstructure analysis of musical behaviours (playing and listening back) are illustrated here by showing auditory feedback available in each of the three case studies according to the musical structure of their respective chosen pieces.

Case study A- lesson 1



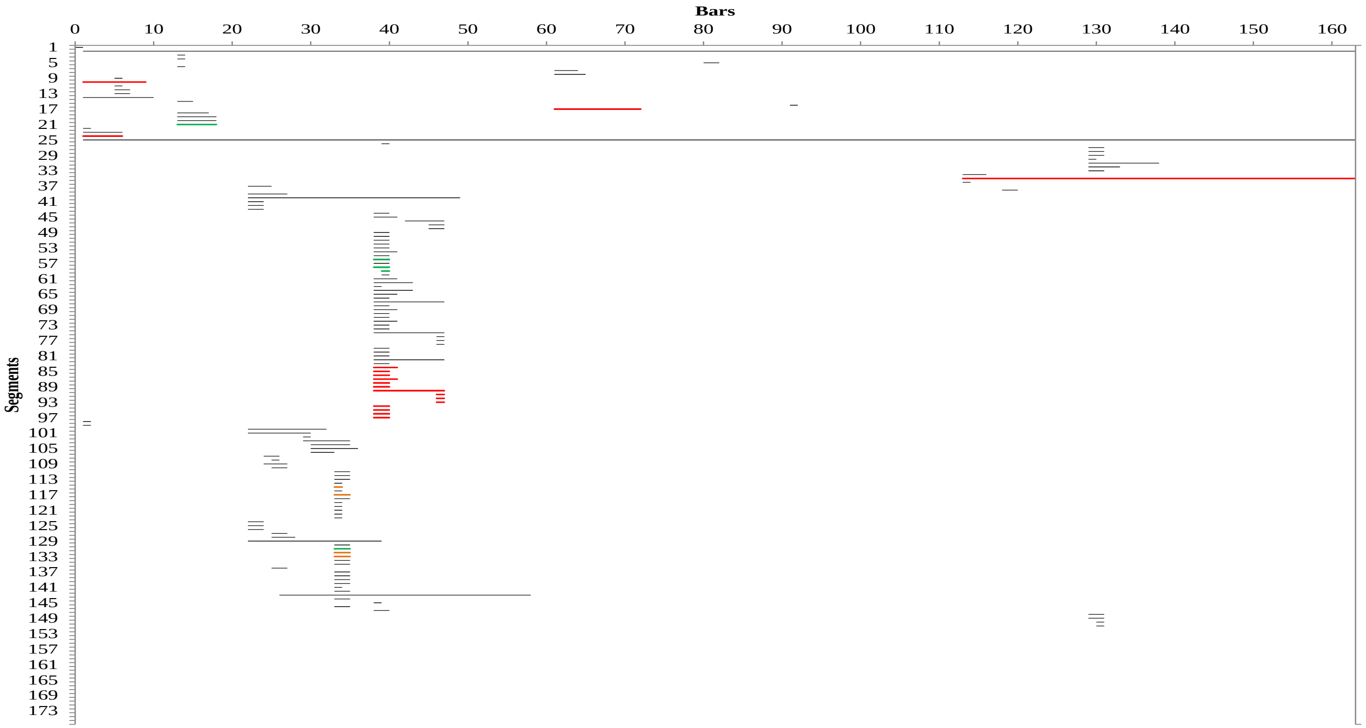
Key: Mozart Piano Sonata No. 16 in C major, K. 545, second movement). This figure shows 91 uninterrupted musical segments versus 74 musical bars. Colour code: Black—real-time auditory feedback by student (student playing); Red—post-hoc auditory feedback by student (listening to recorded performance-related data of student); and Green—real-time auditory feedback by teacher (teacher playing).

Case study A- lesson 2



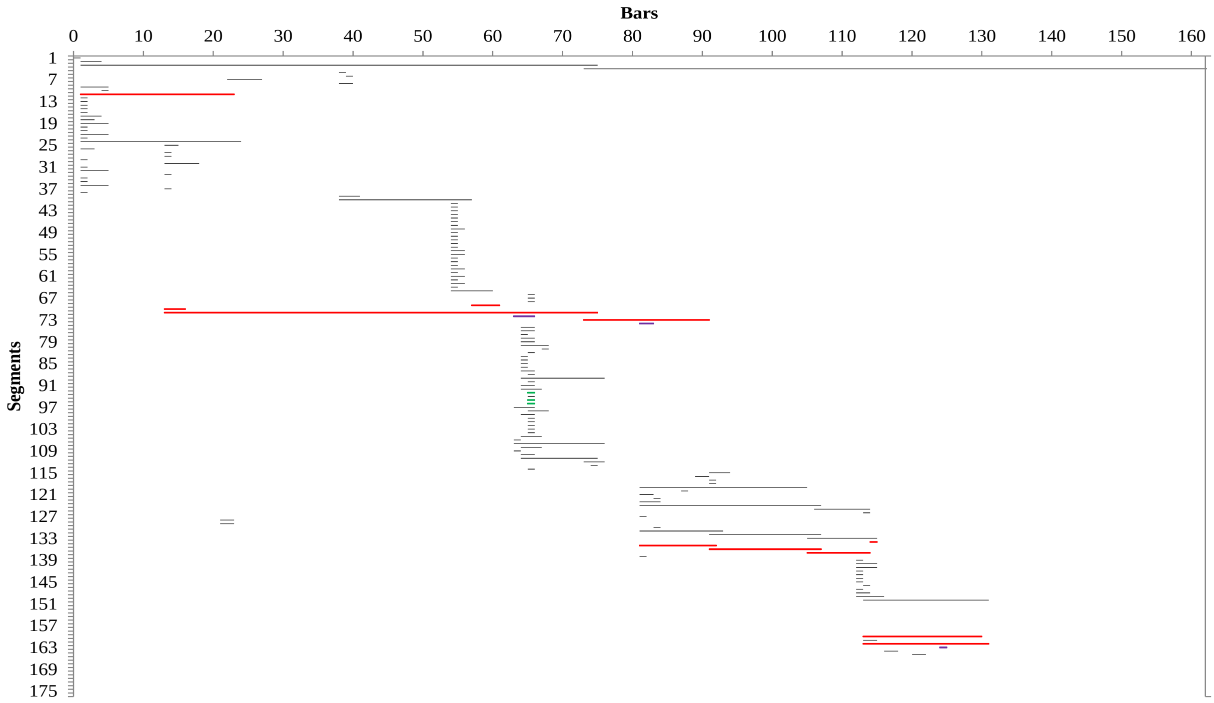
Key: Mozart Piano Sonata No. 16 in C major, K. 545, second movement). This figure shows 88 uninterrupted musical segments versus 74 musical bars. Colour code: Black—real-time auditory feedback by student (student playing); Red—post-hoc auditory feedback by student (listening to recorded performance-related data of student); Green—real-time auditory feedback by teacher (teacher playing); Blue—a combination of real-time auditory feedback by student alongside post-hoc auditory feedback by student (purposeful student playing over listening to recorded performance-related data of student); and Orange—real-time auditory feedback by the teacher playing alongside the student (teacher playing alongside student playing).

Case study B- lesson 1



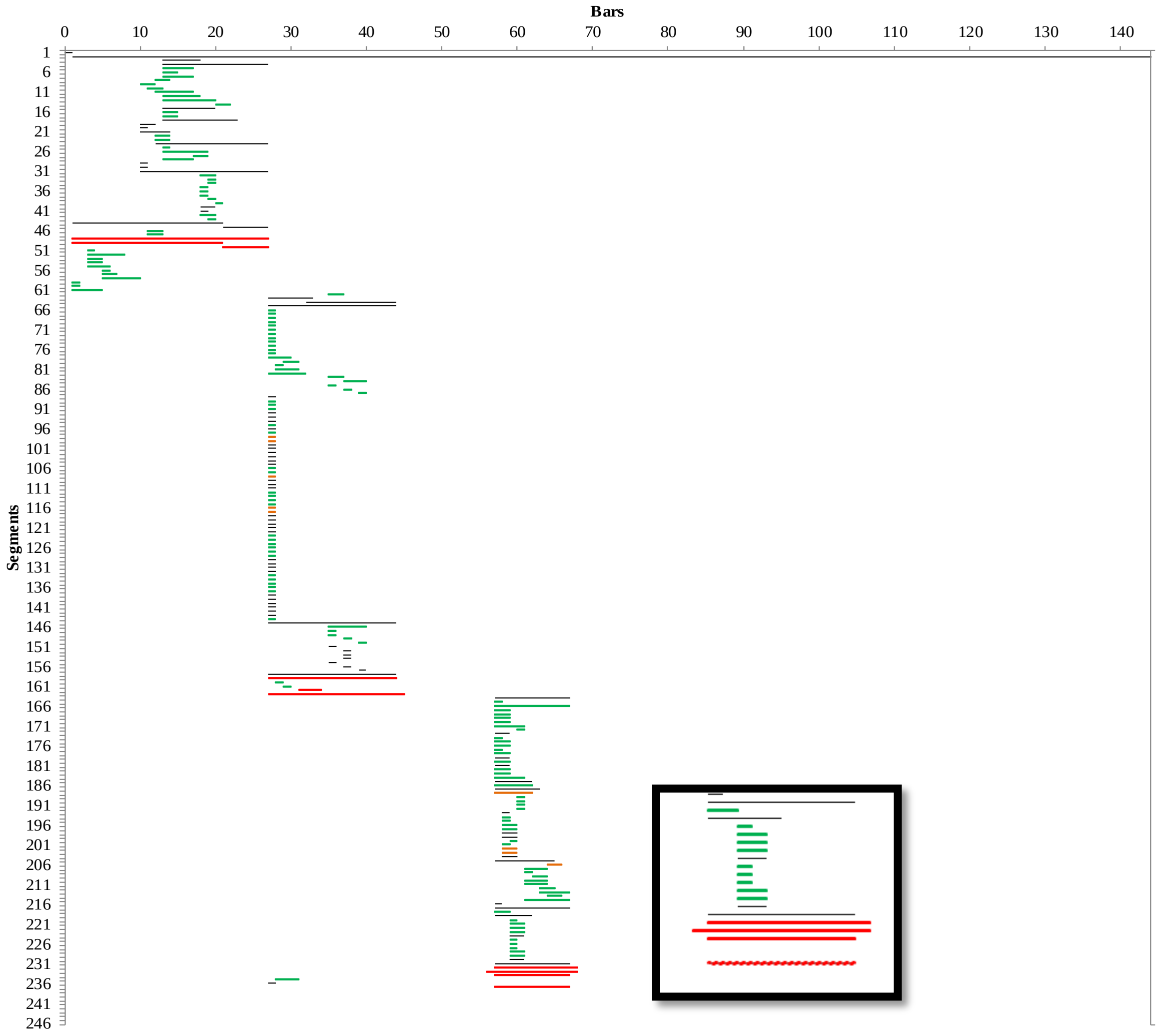
Key: Beethoven Piano Sonata No. 9 in E major, Op. 14 No. 1, first movement. This figure shows 151 uninterrupted musical segments versus 162 musical bars. Colour code: Black—real-time auditory feedback by student (student playing); Red—post-hoc auditory feedback by student (listening to recorded performance-related data of student); Green—real-time auditory feedback by teacher (teacher playing); and Orange—real-time auditory feedback by the teacher playing alongside the student (teacher playing alongside student playing).

Case study B- lesson 2



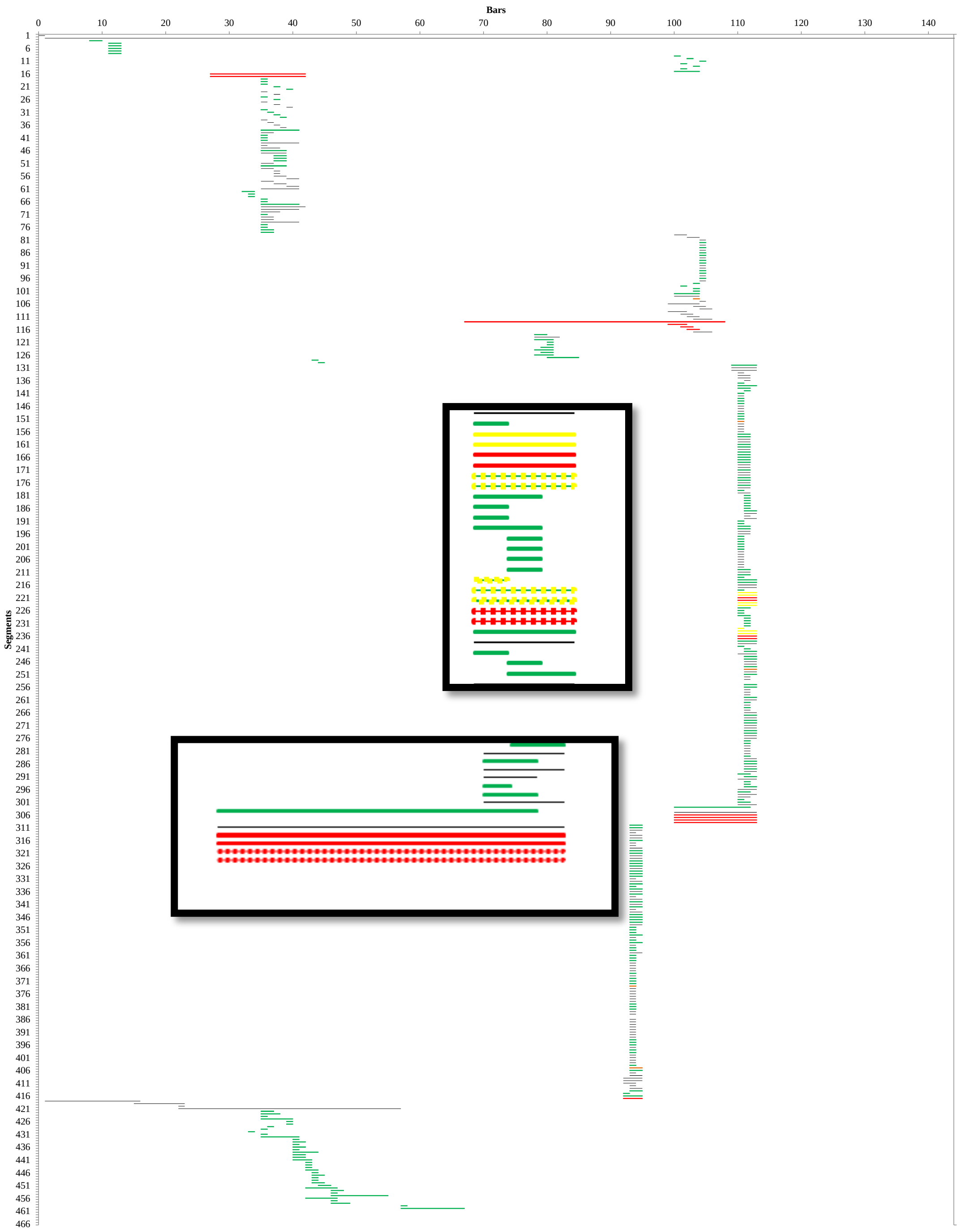
Key: Beethoven Piano Sonata No. 9 in E major, Op. 14 No. 1, first movement. This figure shows 165 uninterrupted musical segments versus 162 musical bars. Colour code: Black—real-time auditory feedback by student (student playing); Red—post-hoc auditory feedback by student (listening to recorded performance-related data of student); Green—real-time auditory feedback by teacher (teacher playing); Purple—a combination of real -time auditory feedback by student alongside post-hoc auditory feedback by student (accidental student playing over listening to recorded performance-related data of student).

Case study C- lesson 1



Key: Mozart Piano Sonata No. 2 in F major, K. 280, first movement. This figure shows 237 uninterrupted musical segments versus 144 musical bars. The detail was shown in Chapter 8. Colour code: Black—real-time auditory feedback by student (student playing); Red—post-hoc auditory feedback by student (listening to recorded performance-related data of student); Green—real-time auditory feedback by teacher (teacher playing); Orange—real-time auditory feedback by the teacher playing alongside the student (teacher playing alongside student playing); and Dashed red—slower post-hoc auditory feedback by student (listening to recorded performance-related data of student at slower half tempo).

Case study C- lesson 2



Key: Mozart Piano Sonata No. 2 in F major, K. 280, first movement. This figure shows 461 uninterrupted musical segments versus 144 musical bars. The details were shown in Chapter 8. Colour code: Black—real-time auditory feedback by student (student playing); Red—post-hoc auditory feedback by student (listening to recorded performance-related data of student); Green—real-time auditory feedback by

teacher (teacher playing); Yellow—post-hoc auditory feedback by teacher (listening to recorded performance-related data of teacher); Orange—real-time auditory feedback by the teacher playing alongside the student (teacher playing alongside student playing); Dashed red—slower post-hoc auditory feedback by student (listening to recorded performance-related data of student at slower half tempo); and Dashed yellow—slower post-hoc auditory feedback by teacher (listening to recorded performance-related data of teacher at slower half tempo).

Appendix 13: Participant perspectives on the application of technology-mediated feedback in HE piano studios

Insights into the application of technology in a piano studio in terms of frequency of use, adequacy of repertoire, and stage of development in the learning process were considered through participant self-reports (Table below). Self-reports were based on participant experiences in only two lessons with application of technology.

Table of participant perspectives on the application of technology-mediated feedback in HE piano studios

Perspectives on the technology use		Frequency of use	Recommended repertoire	Learning process stage of the repertoire
Case study A	Teacher	Every other lesson	Classical, baroque, and contemporary repertoire (avoiding romantic and impressionist repertoire)	Any stage (learning to memorizing the piece)
	Student	Specific lessons, or before live performances	Any repertoire (mainly classical repertoire)	Well-known piece
Case study B	Teacher	Once a month or twice per semester	Any repertoire (avoiding romantic repertoire)	Well-known piece (avoiding sight-reading the piece)
	Student	At least four successive lessons	Any repertoire (mainly contemporary repertoire)	Well-known piece (memorizing the piece)
Case study C	Teacher	Once a month, or once every two months	Any repertoire (avoiding impressionist repertoire)	Any stage (mainly sight-reading the piece)
	Student	Every other lesson	Classical and contemporary repertoire	Any stage (learning to memorizing the piece, avoiding sight-reading the piece)

Some participants also reported additional views on the application of technology in the piano studio. Teacher A believed that it would be beneficial to train teachers in advance on how to manipulate the software in order to help students to perceive the points they wanted to make in their lessons. Student A suggested the use of printable graphs for the dynamic balance between both hands perhaps similar to the one which was shown in Chapter 9 (Figure 9.20). Teacher B made the point of using technology in a group piano lesson where one piano student would be playing a piece whilst the other students observed and reflected on it together. Perhaps in a group piano lesson, students could not only support each other in learning, but also share their previous familiarity with technology.