Language use in Physics inquiry-based learning activities:

A case study of learning Physics in a bilingual classroom in Malta.

by

Naomi Attard Borg

A PhD Thesis submitted to the

Institute of Education, University College London,

in fulfillment of the requirements for a PhD degree

January 2023

Declaration

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

Abstract

Students' performance in science subjects has often been associated with lack of conceptual understanding (Matriculation and Secondary Education Certificate Examination Board, 2018). Research shows that in countries where the language of instruction is different from the students' home language, this has an impact on their conceptual understanding as well as on their performance in formal assessments (Charamba, 2021; Charamba, 2020a). This study was carried out in a secondary state school in Malta, where both English and Maltese are official first languages, but Physics is taught and assessed in English. It involved action research where, as a Physics teacher, I implemented a number of inquiry-based activities with one group of my students at the secondary state school where I taught. The group was composed of five students: a foreign student who understood Maltese but spoke solely in English, two first language Maltese speakers proficient in both Maltese and English and considered parallel monolinguals, and two first language Maltese speakers with low proficiency in English and hesitant when expressing themselves in English. When inquiry-based learning activities were implemented in the first cycle with strict use of the English language, I observed that the students struggled to express themselves. In the second cycle I still used inquiry-based learning activities but encouraged the students to express themselves in their preferred language (English, Maltese or code-switching). From my analysis I could conclude that when the students were allowed to speak in their preferred language, they often resorted to Maltese and code-switching. Their contributions towards the discussions increased in frequency as well as in the quality of their insights when attempting to provide sophisticated explanations. This study has shown that adopting inquiry-based learning approaches where my students spoke in their preferred language helped them to express deeper meanings. This study concludes that in a bilingual context like Malta, learning science in one's second language was a hurdle for my students. However, they also became more aware that they need to learn how to express themselves well in English when talking physics. These results highlight how language impacted my students' learning, and that as their teacher I had the responsibility to teach the language of science together with conceptual understanding.

Impact Statement

The findings that emerged from the study underpinning this thesis provide insight into the impact which the language used in the classroom may have on the learning of Physics in the Maltese context. This is of particular interest as English has remained the official medium of instruction in the state secondary education system, many years after Malta's independence from British rule in 1964 (Constitution of Malta, 1964). Although the Maltese Constitution considers English as an official language alongside Maltese, sociolinguistic surveys carried out have highlighted the decline in English language use among students, with English becoming more like a second language (Schriha and Vassallo, 2001). It is unfair to consider all Maltese speakers as parallel monolinguals, as many students tend to have varying levels of English proficiency.

The findings of my study shed some insights into how this linguistic landscape impacted my students' learning. The findings inform policy makers, teachers and other educational practitioners with insights about students' struggles when learning in a second language and can influence educational policies related to the language of instruction in Physics as well as for other subjects. The findings may help highlight the value of the language used in the classroom, i.e. the language of instruction during the teaching and learning processes as well as the language used by the students in the classroom when trying to make sense of the physics concepts. Policy makers may engage in discussions with teachers about language use during instruction compared to learning how to talk physics in formal settings such as in assessment. They may consider the option of creating academic spaces which value different language repertoires and allow students to use their preferred language to express themselves during the learning process to enhance understanding, and alongside it also teach the language of physics in English for use in official contexts.

Maltese has limited vocabulary in Physics and science, and this linguistic limitation needs to be addressed if students are to be allowed to speak about physics concepts in the Maltese language. One possible way of addressing this issue is through creating a glossary of Physics terms in Maltese and teaching students how to speak physics and answer questions in formal assessments even for the technical words in Maltese. This is difficult to achieve as the Maltese language is, so far, not endowed with enough vocabulary to cover all concepts in Physics. There exists the National Council for the Maltese Language which can take on this challenge, similar to the initiative taken for the case of mathematics at primary level (Farrugia et al., 2022). Another option would be to allow students to use their preferred language in the classroom during discussions and groupwork and code-switch as much as they want, but then teachers take on the responsibility of teaching them the language of science (with specialised technical terms) and how to express themselves in English. This will enable students to read Physics books in English and respond to questions for assessment in English. National policies may include one or both approaches to language use with the aim of improving students' performance in formal assessments and high-stake examinations. The subject teachers' role as teachers of the language of science would also need to be included in national educational policies.

The results of this study will be of primary interest to practitioners in schools (teachers, curriculum leaders and other educational practitioners) as well as educators who are involved in initial teacher training and teachers' Continuous Professional Development. This study, actually may, also act as a catalyst to restart the debate on language use in education in Malta - a topic which has been raised particularly in the current context of Malta which has changed from bilingual to multilingual classrooms. Locally, the ultimate potential impact is related to bringing about changes in science classroom practice which would benefit students in Maltese schools and improve the quality of learning Physics. The relationship between the linguistic resources of students and how these might be used for thinking, as well as the relationship between conceptual development and subject-specific lexis are relavant to a wider range of different educational contexts.

The research work disclosed in this publication is partly funded by the Malta Government Scholarship Scheme.

Acknowledgements

There are many people to whom I would like to extend my heartfelt gratitude upon the completion of this thesis. Without them, I would not have been able to achieve this academic milestone.

The persons that I cannot thank enough are my supervisors, Dr. Ralph Levinson, Dr. Amanda McCrory and Dr. Mark Hardman. I feel blessed that I have had supervisors who guided me, nurtured me, challenged my ideas and provided me words of encouragements that helped me overcome many difficult situations I encountered throughout this journey to see the completion of this thesis.

To my close friends, especially a particular friend, who is my mentor, my role model, my friend and also like my second mum. Thank who for believing in me and supporting me throughout these years, I truly appreciate.

None of this would have been possible without the love, patience and support of my late parents, who instilled in me the passion to learn and to chase my dreams.

I would also like to express my heartfelt gratitude to my children, Jake and Amber, for encouraging me, cheering me up when I was overwhelmed and also for putting up with me, love you endlessly.

Table of Contents

Table of Tables

Table of figures

List of Appendices

Introduction

1.0 Introduction to the chapter

In this chapter I provide a brief background of what inspired me as a teacher of Physics to want to carry out this research and find ways to help my students understand Physics better. It is followed by a background description of compulsory education provision in Malta and a summary of students' performance in Science and Physics at a national level, which, similar to my concerns, demonstrate how students from State schools do not perform well in science in international assessments. A contextual historical perspective on how English became the official language of instruction in Malta, and how it is still the language of instruction for many subjects within a bilingual setting is discussed. The chapter highlights the struggles, which my students experienced to understand physics concepts and learn the language of physics, in addition to learning Physics in a language (English) in which they have limited proficiency. I explain how I wanted to embark on an action research exercise to improve my pedagogical skills through the use of inquiry-based learning. I also wanted to transform language barriers into tools promoting learning in Physics, while also enabling my students to learn how to use the language of physics appropriately. This chapter ends with an overview of the study's methodology and a summary of the chapters which follow in this thesis.

1.1 Background to the research

The motivation to carry out this research, stemmed from my background as a Physics secondary level teacher in a state school in Malta, who at the start of this research, had been teaching Mathematics and Physics for twelve years. During my years of teaching, I noticed how many of my students experienced difficulties understanding basic concepts in Physics. They struggled to express their ideas and to find the right words to explain their reasoning in English. They lacked the linguistic fluency to use the appropriate scientific language to fully discuss the scientific concepts they engaged with, and to interpret their observations when carrying out experiments or investigations. I also noted how they encountered this language barrier even when writing about their scientific work. They often did not manage to use the right terminology to explain how they applied their scientific understanding to different contexts in their formal reports, as well as in homework, as part of their formative assessment. I noted a similar difficulty when they had to elaborate their answer in their responses in examination papers as part of their summative assessment.

I felt that the students' struggles did not only reflect limited understanding as they grappled with new scientific concepts. They many times also lacked the language skills to identify the right words and scientific expressions to articulate clearly their reasoning and understanding. They often remarked that they did not know how to respond to my questions or to the questions in the worksheets. This indicated that somehow, there could also be a language problem coupled with difficulty in conceptual understanding. Together, I felt that these issues impeded my students from learning Physics effectively. I wanted to understand how I could help their learning by adapting my pedagogical approaches with better designed inquiry-based learning activities. I was also intrigued by how the language barrier was possibly contributing to the difficulty that my students were experiencing when learning Physics. Students were required to learn the technical language of physics in the English language, which although an official language alongside Maltese, was in many cases, still a second language to many students.

As a teacher I was also concerned about Malta's ranking in international studies such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). These studies show that scientific literacy among Maltese students leaves room for improvement. In fact, Malta placed thirty-ninth out of the seventy-two countries participating in PISA 2015 (Ministry for Education and Employment, 2015a) and twenty-second out of thirty-nine participating countries in TIMSS 2015 (Ministry for Education and Employment, 2015b). Both PISA and TIMSS assessments test the students' content knowledge and their cognitive skills. The PISA 2015 Malta Report (Ministry for Education and Employment, 2015a) highlighted that the score of the first thirty-eight countries was significantly higher than that of Malta. This indicates that, similar to what I was observing with my students, there was limited understanding of scientific concepts among Maltese students. In fact, analysing Malta's international performance in both PISA 2015 and TIMSS 2015 (Ministry for Education and Employment, 2015a; 2015b), show that the students who were proficient in the English language performed better as they could both understand questions better as well as express themselves more eloquently (Ministry for

Education and Employment, 2015c, 2015a). I return to this issue on page 253. I felt that there was a need to help my students in both understanding and with their language proficiency as it is possible that proficiency in the English language may be to some degree related to students' performance in science subjects.

While the performance of Maltese students in international assessments should not directly determine what is taught in our schools and influence national education policy, the insights obtained do serve as an eye-opener about the challenges, which our education system faces. These poor performance results do reflect to a degree the struggles that I have noticed among my students. It calls for further research on how to promote better understanding of concepts, as well as support language development in the science classroom.

My years of experience in teaching Physics have made me reflect and conclude that helping my students understand physics concepts well is not enough to consider them able to talk and write physics proficiently. This made me ponder on what I can do as a teacher to help my students understand physics concepts well, and in the process, to also learn how to talk and write about it effectively (Sutton, 1993). It was this reflection on my practice, which motivated me to carry out this research as part of my doctoral studies. I decided to embark on an action research study focusing on supporting my students' learning of Physics and to articulate their answers clearly and accurately. This will, hopefully, help me improve my practice to enable students understand physics concepts better, to use the language of science appropriately, and enhance the quality of science education in Malta.

1.2 Background to the Education System in Malta

In order to be able to understand the value of this research study, one needs to first gain an understanding of the educational context in which it was carried out: the Maltese education system; how it is set up; and how it functions. The school system in Malta is tripartite, with provision by the State, Catholic Church and Independent schools. During the academic year 2016-17, when I started conducted my research and data collection, 57.6% of students attended State schools, 29.2% Church schools and 13.2% Independent schools (National

Statistics Office, 2018). Research shows that school type reflects different levels of student success with students from Independent and Church schools performing better in international studies (also in science) than students from State schools (Ministry for Education and Employment, 2015a; 2015b). While the reasons for such differences are complex, they demonstrate how students in State schools require more support with their learning. This is what I would like to achieve with my students.

Compulsory education in Malta consists of 11 years (Year 1 to Year 11) with children starting formal education at the age of 5. The first 6 years, Years 1 – 6 make-up primary education, which are then followed by Years 7 – 11 of secondary education. Students in secondary school learn general science in the first two years of their secondary schooling, following which they have to choose to study one science subject up to school leaving age. Physics, however, is a compulsory subject in State schools, which means that unless students choose to specialize in science, they study only Physics up to school leaving level.

At the age of 16, that is, the end of compulsory education, students sit for national school leaving examinations called the Secondary Education Certificate (SEC), managed by the Matriculation and Secondary Education Certificate (MATSEC) unit at the University of Malta. Among these subjects one finds Physics, which is assessed in English. At the time of this research, students who obtained a SEC in 6 subjects, of which one science was required, meant that obtaining a SEC in Physics enabled students to proceed to sixth form, which is the general post-secondary education in preparation for entry into University.

This research was carried out in a state secondary school where I was teaching. At the time this research was carried out, students from the same region in Malta attended the same secondary school. There was no formal streaming by academic achievement. This resulted in the classes that I taught being composed of mixed-ability students. Since Physics was compulsory, and many of my students were struggling with understanding the subject, I wanted to improve my pedagogical skills to help my students understand physics concepts better, enabling them to succeed and to proceed to sixth form should they want to go to University.

1.3 Students' performance in Physics

Success in learning Physics for students in Malta impacts 'their disposition toward future study' (Adams et al., 2015, p.2062), whether it is a science-oriented career or not. Ensuring a high level of student performance in Physics becomes important to promote an increase in tertiary graduates in Malta. It is also important to ensure a steady supply of science graduates to the labour market, particularly in research to promote Malta's further economic growth (Ministry for Education and Employment, 2014). This challenge was identified as a major concern in the Ministry of Education and Employment's educational policy - Framework for the Education Strategy for Malta 2014-2024 (Ministry for Education and Employment, 2014) which states that developing more knowledgeable workers who are innovative in the field of Science 'would only succeed if they had access to the knowledge and information in the field' (Low, 2016, p.10).

Trends in secondary students' performance in Physics in Malta can be obtained through the students' performance in SEC national assessment at the end of compulsory education. Past SEC results show that around two thirds (67%) of the Maltese students pass the Physics SEC exam (Pace, 2016; Costa, 2018). These results are considered of importance to the country, often attracting media attention and reflection on the quality of education provision in Malta. The MATSEC examiners' reports on students' Physics performance between 2012 and 2021, however, only reflect slight changes in the percentages of students obtaining a pass. This is mainly due to the use of norm-referenced assessment rather than of a criterion one. It is therefore impossible to draw conclusions about the students' performance in Physics from this data. SEC examiners' reports provide some qualitative insights. They highlighted how a few candidates could not even provide proper definitions of key physics concepts. For example, in defining the concept *work done*, 'only a few listed that the force and displacement should be acting in the same direction' (Matriculation and Secondary Education Certificate Examination Board, 2015, p.6). *Moments* was also flagged as a topic where definitions given left much to be desired as 'the operative word perpendicular was sorely missed in most answers' (Matriculation and Secondary Education Certificate Examination Board, 2017, p.5). These comments highlighted problems related to understanding. Examiners' reports also lamented about the vague responses provided which reflect lack of mastery of the scientific content (Martiniello, 2008). The 2016 and 2018 SEC examiners' reports highlighted how written explanations continued to lack detail and did not focus sufficiently on the specific questions asked. Examiners were of the opinion, that, the lack of detailed explanations and unclear answers to the questions posed correlated with lack of understanding of concepts and principles. This was mainly evident when applying knowledge to 'situations, which were somewhat innovative to them' (MATSEC Examination Board, 2017, p.6).

The reports also demonstrated issues with mode of expression used. Use of correct scientific language, for example, 'the most salient terminology expected, including the Big Bang theory' (Matriculation and Secondary Education Certificate Examination Board, 2017, p.3) were often lacking in the candidates' responses (Matriculation and Secondary Education Certificate Examination Board, 2016). The examiners' reports also highlighted that in some cases, students used words, which 'did not conform to the sentence structure' (Matriculation and Secondary Education Certificate Examination Board, 2018, p.7). There were also instances where students demonstrated difficulty in expressing themselves correctly and that certain responses were 'by no means considered as acceptable' (Matriculation and Secondary Education Certificate Examination Board, 2015, p.4). Lack of detail in the candidates' responses also reflected the students' inability to understand what the examiner was asking for (Deguara, 2009). For students to be able to articulate their reasoning correctly, they need to first understand what is being asked. The examiners' comments thus questioned both the candidates' understanding as well as their proficiency in the language used for assessment, specifically, the use of scientific terminology and English. As a result, it can be argued that, in addition to lack of understanding of concepts and principles, students may also lack the required language competence to express themselves well in the English language. This flags an ambiguity in interpreting the examiners' reports as there is the possibility that the students' grasp of the 'language game' inherent in the completion of science exam papers is weak and also, that the students' understanding of the language of science is weak.

There are different levels of student proficiency in the English language reported across school types, with Independent schools doing better than Church and State schools (Ministry for Education and Employment, 2015a). This is evident from a young age, with students attending Independent schools performing better than students attending Church and State schools in the English benchmark exam at the end of primary school (Ministry for Education and Employment, 2015d). Independent schools have also been found to perform better in science (Ministry for Education and Employment, 2015a). It thus can be argued that the proficiency in English among students attending Independent schools is very good. This raises the question of whether there may be a correlation between the students' proficiency in the English language and their performance in Physics. If students can understand questions better as well as express themselves better in their response, then those with higher English proficiency may perform better. It seems to me that, without sufficient command of the language used in assessment, my students may not perform to their highest potential, even when they may actually possess the required scientific knowledge. This indicates that the language of the assessments may have a significant role in determining the academic achievement of Maltese students. This concern was flagged by 60% of the teachers who participated in a study analysing the teachers' views on international tests (Malta Today, November, 2018). It highlighted how, to perform well in assessment, students may require a basic level of English proficiency to be able to properly demonstrate understanding in Physics. For this reason, students with low English proficiency tend to be at a disadvantage (Kieffer et al., 2009). The correlation between, proficiency in the test language and subject performance has been noted by several researchers (Deguara, 2009; Henry et al., 2014). This implies that in Malta, low performance may not necessarily reflect only lack of scientific knowledge.

Assessment trends highlight the need for students to possess better understanding of physics concepts as well as an improvement in their ability to express themselves in English and, also in using scientific terminology. Both content knowledge to be learnt and proficiency in the test language need to be addressed if more students are to engage actively with learning Physics. There is thus also a strong argument at national level, for researching how content knowledge in Physics can be promoted by considering the role that language plays when learning in a bilingual setting.

1.4 Language of instruction in Malta

It is important to also understand the linguistic landscape in Malta's educational system as part of the context of the study. The Maltese state education system presents a complex language context. There are mixed realities between the use of English and Maltese as language of instruction across different subjects and school types. English is the official language of instruction for secondary Physics. The actual language of instruction in schools, however, varies in the degree of use of English and Maltese across the different school types (Vella, 2019).

A historical perspective can help explain how English became the main school language of instruction in Malta. The issue of the preferred official language can be traced back to the eighteenth century, when Malta experienced a political conflict about whether Italian or English language should be assigned functions in the administration (Camilleri Grima, 2013). This lengthy struggle "language question" led to English eventually replacing Italian as the country's official language (Ministry for Education and Employment, 2015d). Despite this, Italian remained the language of instruction at schools (Zammit Mangion, 2000). In 1934, Maltese became the official language alongside English (Frendo, 1975). However, the noble gentry and upper classes in Malta still considered Maltese as the language of the uneducated (Frendo, 2018).

Schooling in Malta became compulsory in 1925 (Sultana, 1992). English 'found a place in school for the first time in 1833' (Camilleri Grima, 2013, p.553), but it was only after schooling became compulsory that the English language as a medium of instruction 'started gaining more ground over Italian' (Camilleri Grima, 2013, p.553.). This was mainly because all Heads of primary schools in Malta were trained in the United Kingdom. The use of a strict English language policy was also adhered to by Church schools and then by Independent schools, for many years (Scerri, 2009).

The National Minimum Curriculum (NMC) of 1999 (Ministry for Education, Employment and the Family, 1999) which regulated the compulsory curriculum in

Malta, stipulated that science subjects were to be taught in the English language. This policy was not supported by the National Curriculum Framework (NCF) (Ministry for Education and Employment, 2012), which succeeded it and is the policy document currently in force. The NCF instead, states, that there should be a language policy at College level (a college is composed of, a number of primary and secondary schools for students from a particular region). The latter has somehow not been developed. It is thus not clear what the policy for the language of instruction for science subjects is. However, textbooks and assessment of compulsory science subjects, including Physics are still in English.

A recent study (Vella, 2019) showed that in schools in Malta there tends to be equal use of Maltese and English with sometimes more Maltese than English. The equal use of Maltese and English was dominant in church schools, while the use of mainly or only English prevailed in independent schools. Language use in state schools was predominantly Maltese. Her study further identified a link between the language used at home and that used by the students at school. In fact, the use of Maltese at home prevailed among students attending state schools, while the use of English at home was dominant among students attending independents schools. There was great variety of language use at home by children attending church schools: more than a third speak mainly Maltese; with using one language with one parent and another language with another parent; and using only English almost identical. Vella's study (2019) sheds light on how students attending state schools use mainly Maltese both at home as well as at school, English being more of a second language for these students. This was the case with the students in my study who were first-language Maltese speakers. The varying degrees of use of both languages indicate that the level of proficiency in bilingualism among Maltese students varies, which is discussed in the next section.

1.5 Bilingualism in the Maltese educational setting

Although Maltese is the national language, English and Maltese are both 'the official languages of Malta' (Constitution of Malta, 1964, p.7). This bilingualism has language implications within the educational system. Though Malta is a bilingual country, the level of proficiency in bilingualism among secondary students varies, with English language proficiency ranging from a good level to minimal knowledge of the language. English language proficiency makes it a challenge among secondary level students (Mifsud, 2012). Classroom language practices in state schools vary from strict use of the English language, to contexts where Maltese is the main language used for classroom talk. In fact, it has been noted that a number of teachers tend to either switch between the use of English and Maltese during Physics lesson delivery i.e. when talking, or mainly speaking in Maltese sprinkled with technical words in English (Mifsud, 2012). Moreover, code-switching, which is a term often used in the Maltese educational system to refer to the use of English and Maltese in the same utterances (Camilleri Grima, 2013) is also a ubiquitous practice (Vella, 2013). Written Physics tasks, however, have to be strictly in English. Textbooks used are in English, homework assigned, laboratory report-writing and assessments are all carried out in the English language.

Farrell (2011) carried out one of the major studies on bilingualism in Malta. The framework for Farrell's (2011) study was based on Cummins' threshold hypothesis, which states that bilingual students underachieve when they are taught in their second language only, while 'bilingual students who continue to develop both languages in the school context appear to experience positive cognitive and academic outcomes' (Cummins, 2000, cited in Farrell, 2011, p.336). Is this intended to be across the curriculum, or both languages taught as curriculum subjects? In order to distinguish between the two: By implication Farrell is referring to learning both English and Maltese as curriculum subjects. I believe that when students use both languages during the learning process across the curriculum, it will result in improved cognitive and academic outcomes. In his study, Farrell (2011) investigated whether bilingual competence correlated to high achievement in Mathematics and Physics, by looking at the marks learners obtained for the end-of-year examinations in English, Maltese, Mathematics and Physics. The sample in this study consisted of 1262 pupils: 770 girls and 492 boys who were attending their third year in a Junior school. All the participants were native Maltese speakers. The findings of this study showed that the vast majority of students who obtained high marks in both Physics and Mathematics also obtained high marks in both languages' examinations and that participants who were 'Low in both languages were significantly Low also in Physics and Mathematics' (Farrell, 2011, p.343). The results of this study therefore supported Cummins' suggestion that 'a high proficiency in both languages is linked to higher academic achievement' (Farrell, 2011, p.343).

Ventura (2016) reviewed a small number of research studies on the influence of language in the Maltese educational secondary context. Considering that the formal assessment of science subjects in Malta is carried out in English, these studies focused 'on the students' achievement in science and its dependence on their proficiency in this language' (ibid., p.249) by looking at the 'results in tests in which students are presented with papers set in either English or Maltese or different versions of English. The analysis of the language used in scripts written in a normal science examination; and questionnaires or interviews intended to obtain the students' opinions about the possible influence of the language of the test on their comprehension and overall performance' (ibid., p. 243-244). The conclusions drawn from the analyses in these studies are that the use of the students' first language has an impact on their conceptual understanding as well as on their achievement in examinations and that higher achievement in science examinations 'is associated positively and significantly with a higher … proficiency in the language of instruction and a better score in reading comprehension in that language' (ibid., p. 250). These two papers are important because they are in the Maltese context. Taken together, they suggest that for students for whom Maltese is a first language, but where English is both the language of instruction and the language of high stakes assessments, proficiency in both Maltese and English is associated with enhanced academic outcomes in science although that might in some part reflect an overall fluency in learning. It is not clear from this work how best to develop such strength. Since as explained in section 1.1, I felt that my students were experiencing difficulty in understanding concepts as well as lacking in the language skills required to articulate clearly their reasoning and understanding, the analysis of my research, looks at whether the use of an IBL approach promotes better understanding of physics concepts among my students and improve their ability to verbalise their understanding of the physics concepts presented to them in a language that may not be their preferred language.

Another linguistic phenomenon, which has been identified in the Maltese classrooms is translanguaging. Translanguaging is defined as instances where 'the input is in one language and the output is in another language' (Baker, 2000, p.104). For example, a teacher poses a question in English and the Maltese students answer in Maltese. There is no mixing of two languages within one particular sentence. Wei (2018) describes translanguaging as ‘a process of knowledge construction that goes beyond language(s)’ (p.15), because the students are making motivated choices from the linguistic repertoire at their disposal to make-meaning, as opposed to code-switching, where students tend to use their mother-tongue and code-switch for subject-specific lexis.

Though various researches have been carried out in bilingual classrooms, we still know very little about ‘the actual use of two languages, their distribution, balance and explicit or implicit purpose in lessons’ (Lewis et al., 2013, p.107). Furthermore, despite the use of translanguaging, its effect on the students’ understanding of Physics in secondary level has not yet been studied fully. This research hopes to contribute to the teaching and learning of Physics within a bilingual context, by looking also at the students’ use of language in one of the classes I was teaching.

1.6 A multi-linguistic Perspective

‘Sociolinguistic complexity is experienced at present across the globe’ (Moore et al., 2018, p.349). In fact, Malta has, in recent years, experienced an influx of migrant students in the Maltese Education system from both within and beyond Europe. In 2013, there were 3145 EU nationals and 3459 third-country nationals who moved to Malta (International Organization for Migration, 2015). In the same year, there were a total of 779 foreign students attending Maltese state schools; 408 EU nationals and 371 third-country nationals (ibid.). These students, at times, have little or no knowledge of either the English or Maltese language. They thus find themselves in a situation where they need to understand both language(s) to be able to learn Physics. Local classrooms have now become multicultural and multilingual. Exposure to the language(s) of the school environment and providing opportunities to use these languages may help or hinder learning. Classroom talk is considered as a powerful educational tool (Pierce and Gilles, 2008), which enables students not only to share and construct knowledge, but also to build relationships among themselves. The linguistic context of local schools is thus intertwined with learning, also in the case of Physics.

1.7 Aims of research

The challenges of understanding physics concepts and the complex linguistic learning context in Malta may be the barriers hindering my students' learning. They place greater need to provide my students with opportunities to both understand physics concepts as well as to learn how to express themselves both orally and in writing in English, the official language of assessment. It is my opinion that only when my students can "talk science" (Lemke, 1990) that effective learning has taken place. This is why, my study focused on both improving my pedagogies as well as language use and proficiency. The aim was to support my students' learning process to understand physics concepts as well as to be able to "talk physics". I intended to study the effect of using the pedagogy of inquiry-based learning while also being sensitive to the language used when students explain phenomena in their own words and to express themselves well in English when demonstrating their learning of Physics.

The language of Physics is already a challenge to students learning Physics in their native language (Wellington and Osborne, 2001). Maltese students are faced with a double challenge; learning the language of Physics and learning Physics in their second language. Since language and understanding are intertwined, Maltese students need to overcome these two obstacles. Research has shown that when students are afforded opportunities to discuss and use their ideas, they are actively involved in the learning process. These discussions enable the learners to 'feel a sense of ownership towards the knowledge gained' (Halim et al., 2012, p.120) as well as enhance their understanding of content (Harris and Rooks, 2010; Windale, 2001).

Adopting an inquiry-based learning (IBL) approach in Physics has been promoted as a pedagogy to enhance the students' ability to discuss what they are doing, improving their ability to "talk science". In wanting to improve my pedagogical approach, I wanted to experiment further in how I can use the IBL approach to help students develop their language proficiency alongside understanding. I also wanted to research whether it was possible to transform linguistic barriers into pedagogical tools which promote better understanding and greater awareness and proficiency in the language of assessment among my students. The use of

IBL falls within the policy stated by the National Curriculum (Minister of Education and Employment, 2012) which envisaged a pedagogical shift claiming that 'traditional ways of teaching will now be replaced by a more student-centred and inquiry-based approach to learning' (p.25). IBL has often been used interchangeably with other terms such as hands-on, active learning and student-centred (Goodchild et al., 2013). I wanted to test which type of inquiry approach, structured, guided or open inquiry (Tafoya et al.,1980; Staver and Bay, 1987; and Colburn, 2000) was most effective with my students. In either of the types of inquiries, students need to engage with the concept or context they are presented with, explore together, explain their observations, elaborate on their observations as well as on their previously acquired knowledge to draw a conclusion. In an IBL approach, students need to be minds-on, thus, they are actively engaged with physics concepts. This might result in my students understanding Physics better, as IBL approaches provide opportunities and experiences to 'construct and solidify scientific understanding' (Huerta and Jackson, 2010, p.207). The aim of this research was to find out whether it was possible to adopt an inquiry-based learning approach with a focus on promoting language use (technical and everyday) as a "vehicle" that promotes better understanding of concepts as well as greater proficiency in talking about scientific concepts in Physics.

The potential benefits of interactions between students for understanding (Mercer et al., 2004) instilled my interest in studying talk within a bilingual context when using an inquiry-based approach in my classroom. Since English is the official language for formative and summative assessments in Malta, I would like to promote more talk and discussions within an inquiry-based learning strategy in Physics classroom that supports students' understanding in Physics and their ability to talk formal Physics in English.

This study was thus guided by the following two research questions:

- Does an inquiry-based approach enable students to construct knowledge of physics concepts among themselves and with their teacher, even when learning in a language that may not be their preferred language?
- How does a bilingual approach impede or support students in constructing knowledge of physics concepts in a linguistically-mixed group?

This research was carried out with the students I teach, and who struggled with Physics. I wanted to focus on the students' language barrier that varied in level of proficiency while also tackling the conceptual difficulty they experienced in learning Physics. This investigation focused on finding out whether adopting an IBL approach supported learning within a bilingual approach, developing their proficiency in the scientific language in the process of learning Physics.

I carried out this research with my own class as action research. It involved two cycles of research with the same group of students over two years. It involved planning, implementing and analysing trialling a number of structured and guided inquiry activities, as well as different approaches to language use during discussions and formal exchanges. Reflections on one activity guided the planning of the following activity. More than one method for data collection was adopted to ensure triangulation. These included, document collection such as field notes, audio recordings of lessons and transcripts of class conversations. Semi-structured interviews were conducted after the field notes and the transcript of each activity were analysed. The findings that emerged from the analysis of the transcripts of the three IBL activities carried out during Cycle One served to shape the research question for Cycle Two.

The study could help me develop my practice and help my students learn Physics more effectively. It could also shed light on whether an IBL methodology sensitive to the students' complex language context use could promote better learning of Physics.

1.8 Concluding Remarks

This chapter introduced the context of my research study. It presented the cognitive and linguistic challenges that my students faced when learning Physics. It explained how not only my students struggled to understand physics concepts, but they often struggled with the language of instruction and assessment different to their preferred language in and out of the classroom. I shared my class observations to justify the need for this study, as well as highlighted how what I was observing in my class was in cognizance with results obtained from Maltese students' performance in national examinations (SEC) as well as in international studies like TIMSS and PISA. This introduction presented my intention to research whether it was possible to use IBL more effectively while experimenting with language use to help my students perform better in Physics. I explained why I decided to do action research with a group of my students over a period of two years. I presented the starting research question, which guided the first cycle of this study where the students were encouraged to use strictly the English language, and the second research question, which was refined as I moved from one data collection cycle to another, where the students were given the liberty to use their preferred language when engaged in discussions.

The next chapter begins with presenting a review of the literature about the role of the language of science in learning science as well as the role of the language of instruction in learning science in a bilingual context. A review of the literature about inquiry-based learning in general and in science education, mainly Physics is also discussed, followed by an outline of the role of the teacher in a student-centred approach, based on the judicious assistance and support needed by the students to develop an IBL classroom.

Literature Review

2.0 Introduction to the chapter

The aim of this study is to find out how far an inquiry-based learning approach supports students in building knowledge and elaborating their ideas through an open discussion. This chapter seeks to provide a synopsis of the issues pertaining to the use of an inquiry-based strategy where exploratory talk (Mercer and Dawes, 2008) will be encouraged for teaching and learning sciences, particularly Physics. This chapter also discusses the role of the teacher in developing an inquiry-based classroom and the role of language in a bilingual environment, where talk thrives. The contextual constraints and the teachers' dilemmas will also be looked into, as these cannot be overlooked if, as a country, we want to improve the teaching and learning of Physics.

It is not enough for students to understand Physics concepts and demonstrate their understanding in everyday language and then struggle with the vocabulary of science, because in science education, learning the vocabulary of science is essential (Brown and Concannon, 2016). There is growing evidence that supports the idea that a 'synergistic relationship' (Ricketts, 2011, p.56) exists between inquiry and scientific language development. This gave rise to my interest in finding out, whether when a language barrier coupled with difficulty in understanding seem to impede students from learning Physics effectively, adopting an inquiry-based learning approach might result in a 'vehicle' that encourages learners to share their thoughts and findings during the Physics lesson, promotes a better understanding of concepts and in the process, enhances their proficiency in talking science using scientific language appropriately.

Rocard et al. (2007) have reported that European students' interest in science has declined over the past 15 years. Looking at how science education can be improved to ensure scientific literacy among our students is vital as science and technology are crucial for the economic development of any country, as scientific developments contribute to industries and economies (OECD, 2011). Moreover, every country needs to have the skilled workforce for the jobs created to ensure constant economic growth (ibid.). These different rationales for the importance of science education highlight the need to investigate ways in which the teaching and learning of Physics can be improved.

2.1 Students' interest in science education

The decline in students' interest in science is considered to be the result of ineffective pedagogies in science education (Rocard et al*.,* 2007). Europe has given considerable attention to science education in the last twenty years (Osborne and Dillon, 2008) to counteract the decline in interest in science subjects and careers. The designing of science activities to promote future participation in science has been advocated for a number of years (Ainley and Ainley, 2011). It was in fact argued that a shift towards active learning approaches would counteract this decline (Rocard et al., 2007). How the literature defines active learning approaches and inquiry, as well as how it promotes inquiry and inquiry in science education are discussed in sections 2.4, 2.4.1 and 2.5. Alongside ineffective pedagogies, research has also shown that the language of science, being a technical language 'sets up a barrier to comprehension, which for some pupils, may appear as an impenetrable discourse beyond their ken' (Wellington and Osborne, 2001, p.66). This makes the language of science 'a major barrier (if not *the* major barrier) to most pupils learning science' (ibid., p.2). The role of the language of science in learning science is presented below.

2.2 The role of the language of science in learning science

Research over the last six decades (Roberts, 2007; Arons, 1983; Hurd, 1958) has shown that for students to be considered scientifically literate, they need to be 'knowledgeable about science topics, concepts, processes and methods' (Hand et al*.*, 2010, p.49) as well as competent at interpreting and creating science texts (Norris and Phillips, 2003). Therefore, for students to be considered as scientifically literate, they need to be able to demonstrate their scientific understanding both orally and in writing. For students to be able to talk and write science effectively, they need to learn the technical language (language of science) (Wellington and Osborne, 2001; Farrell, 1996).

A study carried out in Malta provides a clear example of how the technical/language of science is a barrier to most pupils learning science in Malta

(Farrell and Ventura, 1998). Their study aimed to find out whether word understanding in post-secondary science education is a problem amongst Maltese students. The study focused on polysemous words: words possessing ‘diverse everyday meanings from the specific scientific denotations they require in Physics’ (p.247). Their findings showed that words such as “power”, “naked”, “field” and “marked” were understood in one particular sense and misunderstood when used in a different context. The expected threshold was not reached despite the sample being pre-university students and amongst the top 15% to have made it to this level. Though it might have been precisely the polysemy that created the problem, it can also be inferred that their findings provided insights that the technical language of science is indeed a barrier to learning Physics in Malta. This shows the need for students to learn the ‘very specific ways of using these words appropriately in a scientific context’ (Schwartz et al., 2009, p.83) as an explanation is not enough for the students to learn the scientific vocabulary (Carre', 1981). Moreover, teaching the students the technical language of science supports learning science and language learning (Lemke, 1990). Taking a social constructivist view of learning, Vygotsky (1987) understands this phenomenon as language being productive of thought, and so as directly supporting conceptual development. In social constructivism, the teacher's (and more knowledgeable peers') role is in part to scaffold a transition between the current use of language and, in this context, the physics community's use of the subject-specific lexis.

Experiencing a difficulty in the technical language of science might be assumed to be the only problem faced by learners learning science. In a bilingual context like Malta, learning science is even more complicated, as in the case of Maltese students one finds patterns reflecting a mix of two languages. Moreover, the proficiency in the English language among our students varies. For some, the English language is a second language. In the literature, learning science in a second language has been pointed out to be a barrier to the students (Lodge, 2017; Nyika, 2015; Miller, 2009; Rollnick, 2000) as these learners might experience a difficulty in the language of instruction, possibly a result of the difference between what the teacher says and what the students understand (Muralidhar, 1992). This means that in classrooms where students are expected to demonstrate their understanding of concepts in a language they are not competent in, their lack of competency presents various challenges (Tobin and

McRobbie, 1996). Thus, the language of instruction plays a fundamental role in learning science. The role of the language of instruction in learning science in a bilingual context is discussed in the section below.

2.2.1 The role of the language of instruction in learning science in a bilingual context

Available literature shows that a monolingual pedagogy is a key factor in bilingual and multilingual students' academic underachievement in science exams, even if it focuses on students achieving conceptual understanding (Charamba, 2021; Charamba, 2020a). Research in the science classrooms has also pointed out that such challenges are very likely to impact the students' disposition 'toward future study' (Adams et al., 2015, p.2062) in science subjects. Thus, it is important to look at how this achievement gap can be reduced and how science can be accessible to a wider variety of students.

Language is viewed as the most important resource for communication and learning (Dewey, 1998; Charamba, 2020b) and spoken language is often 'used as a means for teaching and for students to demonstrate to teachers what they have learned in the classroom' (Low, 2016, p.38). Thus, all students should be given opportunities to participate in interactional practices, regardless of their proficiency in the language of instruction and language of assessment. Therefore, it is important to create an academic space that values different language repertoires, as such a space is a key that promotes science literacy among bilingual learners (Garza and Arreguín-Anderson, 2018). Bilingual learners are referred to in the literature as speakers who make 'use of more than one language' (Moore et al., 2018, p.343) in the same utterance. The idea that a competent bilingual performs as a monolingual in different languages, is referred to as parallel monolingualism (Heller, 1999) or linguistic solitudes (Cummins, 2008). In fact, bilingual individuals are expected to be balanced bilinguals (Charamba, 2020b), and are assumed to have 'developed an equal measure of competence in two languages across any given context and with any given speaker' (Infante and Licona, 2021, p.914). This means that bilingual students are expected to perform exactly as a monolingual speaker of each language (Charamba, 2020b). In theory, balanced bilingualism is totally possible, in practice, it is not so likely as one can be fluent in everyday conversation in both languages, but fluent only in the home language, when taking into consideration academic sentence structures (which is a form of literary) (Medoza, 2021). Despite this, the idea that students are balanced bilinguals is still dominant in Maltese state schools. In fact, although many researchers are in favour of local languages as medium of instruction and restricting the use of English in post-colonial countries, English has remained 'the official medium of instruction even after the British colonization' (Low, 2016, p.51) in Malta. Thus, Maltese students are considered as parallel monolinguals, even though for some of our students, the English language is a second language. This means that Maltese students 'not only must acquire the discursive practice of the scientific field' (Poza, 2019, p.2) which is like a 'foreign culture' (Aikenhead and Jegede, 1999, p.269) to most students, but they also have to learn the content in a second language. Thus, the section below looks at the relationship between the use of the students' first language and learning science.

2.2.2 The use of the students' first language in learning science

When teaching science in a second language, research has demonstrated that effective science teachers 'make use of the students' home language to support science learning' (Lee and Buxton, 2013, p.40) and to clarify their thinking. After all, the emphasis should be 'on making meaning, on hearing and understanding the contributions of others, and on communicating their own ideas in a common effort to build understanding of the phenomenon' (Lee, Quinn and Valdés, 2013). Garza and Arreguín-Anderson (2018) contend that in their research with 16 fourth-grade students, the students could navigate between languages as language flexibility was encouraged in the classroom. This resulted in the emphasis being 'placed on meaning making rather than language correctness or language boundaries', (p.109). By having an opportunity to articulate their thoughts freely as they engaged in oral discussions, students used 2 languages flexibly to achieve understanding. In fact, they reported that when the students wanted to explain a scientific concept or idea, 'they expressed it by reverting to the language they felt most comfortable with to demonstrate their understanding of the concept' (Garza and Arreguín-Anderson, 2018, p.112). In other words, the students contributed to the science discourse in a way that reflected features of both languages, developing science concepts not exclusively tied to a specific language. In doing so, Garza and Arreguín-Anderson (2018) remarked that the students who participated in their study, illustrated Cummins' (2000) notion, 'that knowledge is not language bound' (p.112). Their study further showed that when the students were encouraged to use language flexibly, the students seamlessly navigated 'language-intensive and cognitively-demanding scientific tasks' (p.113), which allowed the lesson to move forward. Allowing the students to use languages flexibly has also been reported to improve students' academic performance (Low, 2016). Karlsson et al. (2019) studied the effect of the students' use of their first and second languages in a science classroom at a primary school in Southern Sweden for 3 years. Their study also demonstrated that bilingual and multilingual students should be enabled and encouraged to use all available language repertoires in class, as the use of students' mother tongue promoted a deeper understanding of the science concepts, resulting in improved academic performance. Using different language repertories in the science classroom does not only mean that different languages are used for different purposes, but it also refers to the use of code-switching, which has been defined as the ability to alternate between two languages, when speaking. Code-switching can involve a word, a phrase, a sentence or sentences (Msimanga and Lelliott, 2014).

2.2.3 The role of code-switching in a bilingual context

Since the mid-1970s, the focus of studies of classroom discourse was mainly on how the teachers communicated using a code-switching approach, which is often used in educational systems to refer to the use of the language of instruction and the students' first language in the same utterances. In the 1980s-1990s, studies of code-switching focused on how it 'contributes to the interaction between teachers and learners' (Low, 2016, p.49). These studies have shown that in bilingual education, it is common that at least two languages are used as medium of instruction in the classroom. Several researchers have pointed out that code-switching does have many advantages and useful pedagogical functions in the classroom (Baker, 2011; Garcia, 2009; Low, 2016). Apart from the pedagogic functions of code-switching, several researches have also found out that code-switching was often used for classroom management and to build relationships (Ferguson, 2003).

Focusing on the pedagogical functions of code-switching in classrooms, the most common function pointed out by researchers is that code-switching is 'a way of guiding the students to understand the academic goal' (Low, 2016, p.52). In science classrooms, code-switching can facilitate the explanations of scientific concepts (ibid.) as well as facilitate the 'elimination of misconceptions and formulating ideas' (Rollnick and Rutherford, 1996, p.101). Furthermore, code-switching is useful to encourage and elicit students' participation (Martin, 1999) and to enable the students to discuss logistical matters during group work.

In post-colonial countries like Malta, 'ideological views favouring English as the language of science prevail' (Garza and Arreguín-Anderson, 2018, p.105). In fact, in Malta, English is regarded as a language of superiority, power and success (Tse et al., 2007; Low, 2016). Moreover, the idea that Maltese students are competent bilinguals and thus perform as monolinguals in different languages, is still dominant in schools, despite the fact that, the exclusive use of English in our classrooms has been flagged as not being a beneficial policy multiple times (Farrugia, 2009a; Farrugia 2009b). Thus, when the content is taught in a language that they are not familiar with, as is the case in Malta, classroom code-switching can be considered 'a strategy to promote fast and easy understanding among the students' (Kamisah and Misyana, 2011, p.240). Code-switching tends to be more effective than a monolingual pedagogy (Camilleri Grima, 2013) when the language of instruction is different from the students' first language and can be considered to be, 'extremely beneficial for the effective management of learning processes and teaching activities' (Ministry for Education and Employment, 2015c, p. 41).

To facilitate conceptual understanding 'deliberate efforts to make instruction comprehensible are crucial because as students move in the bilingual continuum, they are likely to exhibit varying levels of command in both content and language' (Garza and Arreguín-Anderson, 2018, p.102). This means that the students' different language repertoires should be exploited and that this should be the norm and not the exception in bilingual classrooms. Allowing students to use their linguistic repertoire means students flexibly use language to i. understand a given task; ii. construct meaning; and iii. clarify their thinking (Creese and Blackledge, 2010, Garcia, 2014 and Lee, Quinn and Valdés, 2013).

Though many studies have provided evidence that code-switching is beneficial as a classroom practice, many still lambast the use of code-switching as 'bad-practice' (Martin, 2005, p.88). A common concern expressed among researchers against the practice of code-switching in classrooms is that although teachers explain a concept in students' mother-tongue, 'students are still required to produce the content in Englihs when it comes to formal examination' (Low, 2016, p.57). Thus, adopting a code-switching approach may affect students' ability to answer questions in Englihs, and consequently, they do not demonstrate fully their content knowledge, as the use of code-switching will decrease the students' exposure and use of the formal language of assessment in science (Gauci and Camilleri Grima, 2012). This 'would counter the productive effects code-switching has on the lessons' (Low, 2016, p.59).

After discussing the advantages and disadvantages pointed out in the literature about classroom code-switching, it can be concluded that code-switching is like a double-edged sword. In fact, the use of English as the medium of instruction in classrooms where the students' first language is not English, which is the case in many Maltese state schools, might see a greater gap in performance between students who are exposed to the English language even outside school and those whose home-language is Maltese. Thus, code-switching can help reduce the gap in learning science between students with limited knowledge of English, and even of students who 'come from socio-economically disadvantaged backgrounds with limited access to English resources' (Low, 2016, p.57). Thus, allowing the students to use the language they feel most competent in can be considered as a move that may be necessary for 'improving the performance of students, particularly the less able' (ibid., p.29), as well as 'mitigating the inequalities' (ibid., p.29) of accessing education between those who are knowledgeable in English and those who have little or no knowledge of English (Ferguson, 2006). It can be concluded that the use of code-switching is 'congruent with a 'science for all' perspective for closing the achievement gap' between students who are more fluent in English and those for whom the English language is more like a second language.

The above discussion on the use of code-switching in science classrooms, especially in post-colonial countries like Malta, indicates that the mismatch between the students' first language and the language of instruction should be given importance if we want to make science education more accessible to a wider range of students. Code-switching facilitates the development of concepts: I allowed my students to use their preferred language because I believe it could facilitate their understanding as well as support their ability to demonstrate their understanding. I argue that conceptual development is a pre-requisite of success in assessment, necessary but by no means sufficient: if a student cannot understand the questions set in English, or cannot respond to questions using the English language, his conceptual grasp alone will not help him verbalise his thoughts or put his knowledge in writing. As a teacher, I have witnessed instances where underperformance in English-medium exams is related to lack of conceptual knowledge, and others where the conceptual grasp is present but the language remains a barrier to the student evidencing that in an examination.

Apart from code-switching, Conteh (2018) argues that a translanguaging approach 'opens up important questions related to social justice' (p.446) to make science accessible to all students, as a translanguaging pedagogy has been advocated for softening the boundaries between languages (Cenoz and Gorter, 2020, p.2). The following section discusses this approach.

2.2.4 A Translanguaging Pedagogy

Baker (2000) describes translanguaging as instances where 'the input is in one language and the output is in another language' (p.104). Similarly, Cenoz and Gorter (2020) summarise translanguaging as the 'practice of switching the language used in the input and the output in bilingual classrooms' (p.2). García (2009) used the term translanguaging to also refer to how 'bilingual people fluidly use their linguistic resources to make meaning and communicate' (ibid., 2009). The origin of translanguaging can be found in 'Welsh-English bilingual education in the 1980's' (Cenoz and Gorter, 2020, p.2). Translanguaging in Wales was developed by Cen Williams 'to help English speakers use more Welsh' (Baker, 2019, p.180) and thus, in this way, students developed both languages. Over the past decade, translanguaging has proven to be an effective pedagogical practice in a number of educational contexts (Charamba, 2020b; MacSwan 2017; Wei 2018) 'where the language of instruction is different from the home languages of the students' (Charamba, 2020b, p.659).

The use of translanguaging has been advocated in the literature as a pedagogy that might promote better content understanding. In the science classroom, a translanguaging pedagogy offers students increased possibilities for content learning (Gort 2015) as they are able to 'access academic content with the resources already part of their repertoire, while simultaneously acquiring new ones' (Charamba, 2020b, p.660). Sticking to the use of the language of instruction implies that the students 'can only use a limited part of their resources to make meaning of the lessons' (ibid., p.666). On the other hand, providing the students with opportunities to use their first language, enables the students to 'select features in their linguistic repertoire in order to communicate appropriately and effectively (ibid., p.666). Thus, translanguaging can be considered as a powerful foundation for complex cognitive skills such as processing scientific concepts as it 'serves as a vehicle through which thinking is articulated and transformed into an artifactual form' (Swain, 2006, p.97).

In Maltese state schools, instances where a translanguage pedagogy is being adopted have been recently noted (Camilleri Grima, 2013). A common occurrence in a translanguage pedagogy in Maltese state schools is the teacher posing a question in English and the Maltese students answering in Maltese. The teacher, possibly uses the English language to expose the students to the way questions are set in summative assessments, or even because there are foreign students present in class who do not understand Maltese. Although aspects of classroom communication practices in Maltese schools have been investigated by a number of researchers from the University of Malta (Farrell, 1996; Farrell and Ventura, 1998; Mifsud, 2012, Ventura, 2016), the role of the language used and its effect on the students' understanding of Physics in secondary schools have not yet been studied fully.

As discussed in sections 2.2 and 2.2.1, the language of science and the language of instruction are considered as barriers to learning science for some students and a shift towards creating spaces which value different language repertoires can halt and possibly reverse the decline in interest in science education at tertiary level. Moreover, research has also pointed out that ineffective pedagogies are also contributing to this decline in interest. In fact, a shift towards active learning approaches has been advocated to counteract the factors contributing to this decline.

2.3 A shift towards active learning approaches

According to MacLellan and Soden (2004), traditional learning tends to consider students as passive receivers of information, where the pedagogic approach is one of ‘lecturing, note-taking, and memorising information for later recognition or reproduction’ (p.254). This approach has been subject to criticism for a number of years. Hence, in recent years, there has been a trend to promote active learning approaches where students are to be allowed to discuss, propose ideas, give explanations and even ask questions. In other words, be minds-on, particularly in mathematics and science.

But what does an active learning approach mean? It is impossible to provide one universally accepted definition for active learning, since different authors in the field have interpreted terms associated with active learning differently. However, active learning can be defined as an approach that requires students to ‘think about what they are doing’ (Prince, 2004, p.1). While some might argue that this definition could include traditional activities such as homework, (since students have to think about what they are doing), in practice, active learning refers to the learning activities that take place in the classroom, which promote students’ thinking to help them make connections with what they already know, and the new knowledge presented. Thus, for the purposes of this research, the core elements of active learning are considered to include student activity and engagement in the learning process that encourages students to think about ideas and how they are using these ideas, and to learn new knowledge, either by participation or contribution in the classroom activity. In other words, engagement refers to when students are kept mentally active in their learning through activities that ‘require them to engage in argumentation and reflection as they try to use and then refine their existing knowledge’ (Scott Grabinger and Dunlap, 1995, p.19). Students are also kept physically active in carrying out an investigation, observing and collecting information, as they attempt to make sense of what they are doing and exploring (Michael, 2006).

It is important to point out that active learning pedagogies are not new. Socrates himself used problems and questions to guide students to analyse and think about their environment (Scott Grabinger and Dunlap, 1995). As the name itself indicates, a student-centred approach is a strategy for learning or teaching that puts the learner at the centre of the teaching-learning process (MacHemer and Crawford, 2007). Yet, it is important to remember that the so-called 'traditional' learning or direct teaching should not be considered as less important. There needs to be 'an element of traditional instruction that addresses students' understanding' (Burgh and Nichols, 2012, p.1053) of new concepts and theories. Furthermore, a student-centred approach, where students seem to be "doing" lots of things but learn few things, or absolutely nothing, is not an effective active learning pedagogy. For example, a task might be successfully completed by a group even though not all the members understood the method chosen and the rationale behind the adopted method (Holbrook and Kolodner, 2000).

EU-funded projects such as COMPASS (2009), PRIMAS (2012) and Fibonacci (2012), encouraged teachers to shift away from the dominant transmission-based teaching approaches (OECD, 2009; Maaß and Artigue, 2013) towards more active learning pedagogies, mainly inquiry-based approaches, which are student-centred. In Malta, the National Minimum Curriculum (Ministry of Education, 1999) and more recently, the National Curriculum Framework (Ministry of Education, Employment and the Family, 2012) envisaged this pedagogical shift claiming that 'traditional ways of teaching will now be replaced by a more student-centred and inquiry-based approach to learning' (p.25). It was further pointed out that traditional practices may restrict learning, while a student-centred approach will focus on 'co-construction of meaning rather than mere acquisition of knowledge' (Ministry for Education and Employment, 2012, p.31). However, this does not mean that all the teachers in Maltese State schools are adopting a student-centred approach. When a government makes a policy, it does not necessarily follow that practice will change overnight and nationwide, due to the challenges that one will need to overcome. Such challenges might include, but not be solely limited to, the pressure of high-stakes examinations, lack of resources, resistance from parents and students, views of assessment and limited training. This implies that support for teachers should be maintained over time (ibid.). As already pointed out, these constraints as well as the dilemmas teachers face will be discussed briefly in section 2.10, as these constraints cannot be overlooked.

2.4 Inquiry

Minner et al. (2010) pointed out that inquiry ‘was born out of the longstanding dialogue about the nature of learning and teaching, in particular, from the work of Jean Piaget, Lev Vygotsky, and David Ausubel’ (p.475) as their work was amalgamated into the philosophy of learning known as constructivism (Cakir, 2008). Hence, discussions of constructivisim and inquiry have a lot in common (Abd-El-Khalick, et al., 2004), as they have many educational objectives in common, such as highlighting ‘student construction of concepts’ (ibid., p.406).

An inquiry-based activity on density, where the students will be provided with the opportunity to investigate different materials, would provide experiences that would contest their ideas and experiences through the discussions that will take place in the classroom. Such discussions might stimulate the students’ thinking, which in turn, might enable them to understand that the mass of one material per 1ml or 1cm^3 is heavier than the mass per 1ml or 1cm^3 of the other material, thus the first material has a greater density. This will help them understand that the reason why certain objects float, while others sink, depends on the density of the object (given that students would have already been taught that density is the mass per unit volume). This example shows that constructivist ideas relate to IBL. It also sheds light on how IBL can help students draw on their previous knowledge to explain things and to contest their thinking.

The term inquiry does not only correlate with constructivism. In fact, across the literature, inquiry is used in different ways and contexts to describe similar teaching and learning approaches (Engeln, Mikelskis-Seifert and Euler, 2014). This indicates that there seem to be common notions associated with inquiry pedagogies (Abd-El-Khalick, et al., 2004). Furthermore, the number of ways that inquiry has been defined ranges from simple descriptions of how students guide their own learning with minimal guidance from the teachers, to more complicated actions for both the teacher and the student (Furtak et al., 2012). Thus, although inquiry is a widely accepted term, it is also often consolidated or used interchangeably with other terms such as hands-on, problem-oriented, investigative, project-based, student-centred, active learning, inductive and dialogic approaches to teaching and learning (Goodchild et al., 2013). Clearly, the spectrum of IBL conceptions is rather extensive. Tafoya et al. (1980) and

Walker (2007), alongside a number of other authors, have attempted to differentiate IBL according to the type, structure and difficulty of the task, as well as the extent of engagement and responsibility carried by students. Staver and Bay (1987) and Colburn (2000) similarly classify IBL lessons into structured, guided and open inquiry. Within the structured type, students are provided with the problem, the method and the materials to solve it. For a guided inquiry approach, students are given the problem and the necessary materials, but they have to find the appropriate problem-solving strategies and methods. During an open inquiry, the students are fully autonomous, i.e. they decide on the problem to investigate, choose the materials required and discover the right approaches to solve it (see Table 2.0).

The teacher's role in asking follow-up questions built on the students' answers, can serve as scaffolding to support students' development of conceptual understanding (Smart and Marshall, 2013). The importance of students achieving conceptual understanding, 'rather than rote learning of facts or procedures' (Lombard and Schneider, 2013, p.166), has been a persistent issue in science education. In fact, back in 1933, Dewey stated that learning 'is not learning things, but the meaning of things' (cited in Burgh and Nichols, 2012). Thus, considering students as empty vessels or a tabula rasa and just pouring facts and information into their heads, will not lead to meaningful learning and understanding (Ausubel, 1968). Meaningful learning occurs when students are given the opportunity not just to express prior knowledge, but also to exchange findings within the class, especially of value, and also, when they adopt different approaches to investigate or solve a problem (Blanchard, Masserot and Holbrook, 2014). This indicates that students should be provided with the opportunity to make sense of knowledge or 'use the knowledge that they have internalised to generate explanations of their experiences in the world' (Pines and West, 1986, p.584). This eventually leads to conceptual understanding, which can be achieved through the three types of inquiry settings listed here overleaf.

Table 2.0: *Types of Inquiry*

Type	Requirements	Example: To investigate heat losses
Structured-Inquiry	Question/problem, method and materials required are given to students.	1. Students are told that they will investigate what influences heat losses and discuss how heat losses can be minimised in everyday life. 2. Students are given two model houses. Each house has a bulb. One house has one door and one window while the other house has one door, two windows and also a higher ceiling. Students are also given two thermometers and a stopwatch. 3. Students will be told that they first have to, monitor the rise in temperature with all apertures closed, and then the decrease in temperature will all apertures open. 4. A sheet with an appropriate table to record the rise in temperature and the decrease in temperature will also be given to the students. 5. Students are given a set of questions that will guide them to draw conclusions.
Guided-Inquiry	Question/problem and materials are given to students. Students decide the appropriate method.	Steps 1 and 2 listed above will be provided to the students. The students will then have to realise that they will need to record the rise in temperature by keeping all apertures closed and the decrease in temperature by keeping all apertures open. They will also have to realise that they need to keep a record of their data, compare it and draw conclusions. If the students fail to do so, the teacher intervenes to guide and to stimulate their thinking.
Open-Inquiry	Students decide the problem, choose the material as well as the approaches required.	Students will be told that they will need to investigate heat losses around us. They will have to discuss in groups what are the necessary materials needed and the appropriate methods to investigate heat losses.

Rocard et al. (2007) describe IBL as the skill of engaging students in critiquing situations, distinguishing alternatives, planning investigations, researching and forming clear arguments. The way Rocard et al. (2007) describe IBL is in line with the views of Askew et al. (1997), Hmelo-Silver (2004) and Swan (2006), as they described IBL as a student-centred and a collaborative approach. They further described IBL as an inductive approach due the students' requirement to provide some sort of evidence in their conclusions. In a collaborative approach, students are allowed to learn from each other as they voice their opinions, discuss and share ideas, explain the reasons behind their choice of methods and also discuss their conclusions. The way the setting needs to be organised for effective collaborative work cannot be overlooked, as it is important for the groups to be set up in a way that the members work well together (Schmitz and Winsekl, 2008). The members further need to be able to share the same understanding of the aim of the task, otherwise, the opportunity to learn how to 'communicate in a meaningful way' (Blanchard, Masserot and Holbrook, 2014, p.85) during a collaborative approach might be squandered. This further shows that through inquiry-based learning approaches, the students' active involvement in the learning process is required. Thus, it is important to discuss how the terms active learning, student-centred approach and inquiry-based learning have been identified in the literature and how they relate to one another.

2.4.1 Inquiry: An active learning approach? A student-centred approach?

Active learning is based on active engagement in the classroom, collaborations, autonomy and personal relevance (Scott Grabinger and Dunlap, 1995), An inquiry-based setting can be considered as an active learning approach, as it requires learners to be mentally active while engaging in hands-on activities (Bulunuz, Jarrett and Martin-Hansen, 2012). Furthermore, since in an IBL setting students are encouraged to express and test their ideas, then an IBL setting can also be considered to be a student-centred approach. Table 2.1 presents how the terms active learning, student-centred approach and inquiry-based learning have been defined in the literature I have revisited. Moreover, each term has been exemplified.

Table 2.1: *Definitions and Examples*

Term	Definition	Example
Active learning	An approach that requires students to be mentally active in their learning, through activities that involve them in collecting information, thinking and problem solving (Michael, 2006). Put differently, students are presented with tasks, which promote their thinking in helping them make connections with what they already know and the new knowledge.	A teacher might carry out a demonstration where the students will be encouraged by the teacher to suggest an alternative approach, to raise questions about the demonstrations and to also be critical.
Student-centred	A strategy for learning or teaching that puts the learner at the centre of the teaching-learning process (MacHemer and Crawford, 2007).	An activity that allows students to make comparisons and give answers, rather than the teacher dictating correct answers to the students and asking that they memorise them.
Inquiry-based learning	In both guided and structured inquiry-based settings, students are required to give 'explanations based on evidence derived from their work' (Blanchard, Masserot and Holbrook, 2014, p.84), while in an open inquiry setting, students generate their own research question.	In a guided and structured IBL activity, the teacher presents a question to the students and they have to articulate different methods to solve the problem, explain their choice of methods, analyse the results obtained and demonstrate their understanding through the conclusions drawn. In an open IBL activity, the students decide the

		problem, choose the material and the approaches required.

With the above definitions and examples in mind, the synergies between the three terms are evident, and therefore, inquiry-based learning settings can be considered, to be both an active learning approach and a student-centred approach. Since this study focuses on whether adopting an IBL approach in one Physics classroom, promotes better understanding of concepts, it is now time to delve into what inquiry in science education entails.

2.5 Inquiry in Science Education

Across the literature, the term ‘inquiry’ in science education refers to three distinct but interwoven categories: investigating scientific phenomena by using scientific knowledge, learning by engaging in scientific experiments modeled by the processes adopted by scientists, and designing activities that provide students with the opportunity to observe, experiment and analyse (Minner et al., 2010). The five E’s model of inquiry (Bybee et al., 2006) is one example of learning and teaching by inquiry. It is based on five steps: engagement, exploration, explanation, elaboration and evaluation. This model of inquiry is explained in table 2.2 below.

Table 2.2: *Five E’s model of inquiry*

Engagement	Where students become engaged in a new concept by posing questions and presenting different scenarios
Exploration	Where students articulate different methods to solve the problems presented to them
Explanation	Where students explain their choice of methods and the reasons behind their choice
Elaboration	Where students demonstrate their understanding through the conclusion draw in a critical way
Evaluation	Where students assess their understanding

The following is a useful summary of learning science by inquiry: a) learners are engaged by scientifically oriented questions b) learners focus on evidence to address the questions c) learners derive explanations from evidence d) learners evaluate their explanations taking into account alternative explanations and e) learners justify their explanations (Barrow, 2006; Bevins and Price, 2016). Learning science by inquiry can thus be considered as an effective pedagogy for students to become scientifically literate, however, as discussed in section 2.2, learning and using the language of science appropriately and cogently is also important. The next section thus looks at the relationship between inquiry and the scientific language.

2.5.1 Inquiry and scientific language

Students tend to be familiar with certain words used in science which have different meaning from their everyday use. In Physics, words such as, “work”, “energy”, “power”, “force” and “electricity” have different meanings from their everyday use (Powers and Stanfield 2009; Wessels 2013). It would be wrong to assume that if a student knows the meaning of a word in one situation, then the student will equally understand it in other situations (Cassels and Johnstone, 1985). A good opportunity for the students to learn scientific language would be engaging in discussion, which, has been considered to be one of the most valuable vehicles for learning scientific language (Huang, 2006).

Discussions are fundamental in an inquiry-based environment as discussions provide students with the opportunity to have pupil-pupil talk and teacher-pupil talk. During pupil-pupil talk and teacher-pupil talk, the students can share the knowledge they have gained through everyday experiences as well as during previous lessons using everyday language. The teacher can then build on that knowledge or repeat their ideas using both everyday language and scientific language. This in turn, will enable the students to further explain knowledge using scientific terms. Moreover, when students use words, they develop understanding since ‘language development and conceptual development are inextricably linked’ (ibid., p.6). Thus, classroom talk is a powerful educational tool. The functions of classroom talk and the effect it has on the students, as a result of its nature and quality, are delved into in the section below.

2.6 Classroom talk: a powerful educational tool

Talk is the medium through which most teaching takes place (Nuthall, 1999). The topic of classroom discourse started to be given more importance in the 1960s. Studies not only have shown that the most common type of talk that takes place in the classrooms, is dominated by teachers (Wilson, 1999), but also that ‘two thirds of the teacher’s talk consists of lecturing and asking questions’ (Oyoo, 2011. p.25). Moreover, the questions that teachers pose either focus on the recall of facts (Duschl and Osborne, 2002) or are of the style of sentence completion, where the students have to guess what answer the teacher is looking for (Wellington and Osborne, 2001). These types of language interactions do not provide enough opportunities for pupil talk and genuine language development, as they ‘severely restrict the possibilities open to students to contribute thoughtfully to classroom talk’ (Skidmore, 2006, p.507). This infers that though talk is a powerful educational tool, its use is often limited, even though its importance is broadly valued (Pierce and Gilles, 2008).

Talk in our classrooms has both social and educational functions. Social talk and educational talk, ‘work interdependently and concurrently’ (ibid., p.51). The social interactions help students bind to one another in a group or learning community. These social interactions in classrooms are vital for learning and understanding. Moreover, educational talk can be asymmetrical as well as symmetrical (Mercer and Dawes, 2008). When classroom dialogue is mainly led by the teachers, and pupils only provide brief answers, the type of talk is asymmetrical. When pupils work together in groups, the type of talk is symmetrical, as all the members of the group have an equal chance to voice their opinions and share their thoughts. Although it may be true, it does not mean that, in any group, these speaking rights will be exercised equally and, if not exercised equally, it does not mean that the group’s collaboration was unsuccessful.

Although both types of dialogue are fundamental in the classrooms (Barnes and Todd, 1977), not all kinds of talk during collaborative work are of equal educational value. Therefore, both the nature and the quality of talk have an impact on the students’ ‘educational achievement and participation’ (Mercer and Dawes, 2014, p.431). Throughout the literature, the following three types of talk adopted by learners during collaborative work have emerged:

a) disputational talk: disagreement between the group members and individualised decision-making;

b) cumulative talk: learners build positively on what the others have said by repeating, confirming and elaborating. They use talk to construct common knowledge (Mercer, 1995);
c) exploratory talk: learners contribute critically by offering suggestions and alternative hypotheses and justifying their reasoning. Students' reasoning is visible in the talk.

For collaborative work to be beneficial to the students, the discussions that take place among learners have to enable them to develop their language alongside their reasoning skills. One cannot expect the students to know how to talk in groups unless teachers show them how. One possible way how to ensure productive group discourse is by the teacher adopting a dialogic communication approach, where the students' points of view is sought, the students are asked for further details on their views and the other students are asked whether they agree or disagree with a shared idea and to explain their agreement or disagreement to the shared idea (Scott, 2008). Moreover, if a group discussion does not foster the development of language and reasoning skills, the value of group discussions will be fruitless. In addition, it is crucial that students feel comfortable to share their ideas. Students need to feel safe from the threat of being made fun of and ridiculed. Hence, creating 'a classroom environment in which a culture of talk will thrive' (Pierce and Gilles, 2008, p.46) is of utmost importance, as through talk, students explore ideas as they try to share and explain their reasoning to other group members. Moreover, the students' questions and utterances engage them in productive thinking (Barnes and Todd, 1977), which provide them with an opportunity to "think aloud" while trying to understand and come to terms with new knowledge. At first, students' explanations might seem confused and incomplete. This is understandable and expected, as they really are at a stage of exploratory talk. Mercer and Dawes (2008) explain that exploratory talk in the form of thinking aloud, helps students build on their prior ideas, to come up with something new. They further explained that as a result, thinking aloud enhances students' understanding, as they elaborate their ideas so that others can understand what they mean. This indicates that providing students with the opportunity to explain their thinking, even if scaffolded and modified by the teachers, will help them 'take ownership of their knowledge' (Solomon and Black, 2008, p.74). Following Vygotsky's insights about the relationship of thought to word, that ‘thought is not expressed but completed in the word’ (Vygotsky, 1987, p.250), when students are given opportunities to think aloud, such opportunities enable the students *to develop thought for themselves* as when one starts speaking, one does not necessarily know exactly where the thought/utterance is going: this becomes clearer in the moment of utterance. In this way, reflective talk is itself a product of thought. Moreover, exploratory talk enables students to try out new ideas, build on each other’s ideas, create meaning together as well as make connections between everyday and scientific ways, and meaningful learning occurs (Ausubel, 1963). Such an approach is a contrast to rote learning, where students have to memorise scientific views instead of connecting ideas and formulating them in a critical way.

Moreover, for students to learn science effectively, they not only need to understand the concepts, but they also need to be able to use the technical language appropriately. To be able to do so, they need to be provided with several opportunities to use language, i.e. to talk science. One of the strategies, which might help students understand concepts better and overcome the language barrier at the same time, is the use of an inquiry-based learning approach. As discussed earlier in section 2.4.1, an inquiry-based learning approach can be considered as an active learning approach, since it requires learners engaging in hands-on and minds-on activities (Bulunuz, Jarrett and Martin-Hansen, 2012). Besides, when students are given the opportunity not just to express prior knowledge, but also to exchange findings within the class, and when students adopt different approaches to investigate or solve a problem (Blanchard, Masserot and Holbrook, 2014), meaningful learning occurs. Student involvement has in fact been reported to be essential for both conceptual development as well as for scientific language acquisition (Bergman, 2013) and during an inquiry setting, students’ involvement is necessary as they need to discuss with their partners and/or their teacher. This indicates that students should be provided with the opportunity to make sense of knowledge or ‘use the knowledge that they have internalised to generate explanations of their experiences in the world’ (Pines and West, 1986, p.584). Such an opportunity will eventually lead to conceptual understanding. Moreover, Shwartz et al. (2009) describe the discussions that take place during an inquiry-based approach as ‘powerful mechanisms’ (p.47) that help students enhance their understanding and also learn to talk science (Heitmann et al., 2014). In fact, inquiry-based learning strategies are described as a 'gateway for using language to speak' (Huerta and Jackson, 2010, p.207) as well as learn how to use scientific language correctly and cogently, through monitoring and instructional support/scaffolding. Affording the students opportunities to talk, does not necessarily imply that learning and understanding are enhanced, as not all types of talk that take place during collaborative work in our classrooms are of educational value.

The next section discusses "exploratory talk" in an inquiry-based setting, as in an inquiry-based setting, the students are working on understanding by reshaping 'old knowledge in the light of new ways of seeing things' (Barnes, 2008, p.4) and exploratory talk provides the students with opportunities to sort out their 'own thoughts' (ibid., p.5). This makes exploratory talk the most propitious in deepening understanding.

2.6.1 Exploratory talk in an inquiry-based setting

In an inquiry-based setting, discussions are fundamental, and these discussions require using the discourse of science. Moreover, during an inquiry-based setting, teachers guide and join in through the dialogue, without committing to answers, letting pupils exercise more control. This type of discussion is an exercise that helps students 'develop important language and thinking skills' (Mercer and Dawes, 2008, p.40) and also master the official language of science. This means that "exploratory talk" is nurtured in an inquiry-based environment. Though "exploratory talk" is essential to develop understanding, it is also challenging. The challenges alongside the benefits of "exploratory talk" in an inquiry-based environment are delved into in the next section.

2.6.2 Benefits and Challenges of Exploratory talk

The benefits of exploratory talk stem from the fact that thinking aloud helps students draw on previous ideas to come up with something new (Scott, 2008). In exploratory talk students 'engage critically but constructively' (Herrlitz-Biró, Elbers and De Haan, 2013, p.1398) as they share ideas and sometimes they need to elaborate on their ideas, so the other group members understand what they mean. This helps students come to term with new knowledge and the students make their reasoning visible in their talk (Mercer 2000). An inquiry-based environment requires the students to use spoken language to present ideas as clearly and as unequivocally as possible, to reason together by cooperatively analysing and giving possible explanations, and also to consider alternative methods (Mercer, 1995). An inquiry-based setting thus provides the students with the opportunity to explain their thinking, which sometimes needs to be 'modified by the teachers' (Solomon and Black, 2008, p.74). Since exploratory talk enables students to try out new ideas, build on each other's ideas, create meaning together and make connections between everyday and scientific ways, exploratory talk is nurtured in an inquiry-based environment. This provides an opportunity for meaningful learning to occur (Ausubel, 1963), as the students are afforded with opportunities of connecting ideas and formulating them in a meaningful way.

Though exploratory talk is 'educationally valuable' (Rutter, Edwards and Dean, 2016, p.22), the several challenges associated with it need to be considered. Exploratory talk is not easy to implement. Some of the barriers identified in the literature include the necessity to manage behaviour, the pressure put on the teachers to meet targets and increase standards (Mintrop and Sunderman, 2009), vast content to be covered, pupil low self-efficacy and absence of ground rules (Rutter, Edwards and Dean, 2016). Furthermore, Coultas (2012) reports that sometimes, the opposition to learning demonstrated by students at secondary level appears to be so strong, that it can be difficult to convince them to learn through talk. Setting ground rules for successful learning through exploratory talk has been frequently highlighted through the literature. Mercer (1995) highlighted the need to develop ground rules so that favourable conditions for useful talk are created. Sutherland (2010) also advocated ground rules as a key factor in successful exploratory talk for learning. Lambirth (2009) criticizes ground rules when ground rules are set in a way that students are to 'use speech in particular and appropriate ways in the context of education and formal discourse' (p.9) as this can be at the expense of 'community language use which is often positioned as a deficit model of communication (ibid., p.9). Allowing the students to set their own ground rules, ideally in their own ways, by focusing on equal opportunities to talk and to also feel safe to think aloud, which are then further discussed and agreed with the teacher (Sutherlan, 2010) might counter balance the concern put forward by Lambirth (2009), that of imposing on the students the use of formal language rather than their habitual ways of talking.

In addition to the importance of ground rules for the quality of learning achieved through exploratory talk, there are several other crucial factors for meaningful learning to occur. The type of tasks presented to the pupils and the composition of the groups determine the quality of talk (Edwards, 2005). Moreover, it is important that the task presented to the students is one in which the members of the groups have to talk in order to complete it. Favourable conditions for effective exploratory talk involve having groups composed of members who are friends, or at least friendly towards each other (Schmitz and Winskel, 2008), with whom they share the same understanding of the aim of the task, have a shared knowledge of the content required to complete the task and the agreed ground rules to be followed. These further flag, the importance of the teacher’s role in developing an IBL setting. The role of the teacher in an IBL setting is discussed in the next section.

2.7 The role of the teacher in developing an IBL classroom

Orchestrating and facilitating the learning episodes and processes in the classroom is a subtle skill that teachers need to learn and develop for IBL to function well. A common term recurrent in the literature is the role of the *teacher as a facilitator* in supporting student inquiry. But what does the *teacher as a facilitator* role entail? How can a teacher facilitate student learning through inquiry, to work collaboratively, to explore and to communicate their work? I find it critical at this point, not only to define what the term *facilitator* implies, but more importantly, to clarify how undertaking a facilitator’s role transforms itself in the inquiry classroom. Swan (2005), for example, speaks of the teacher being a challenger and an intervener; one who asks open-ended or divergent questions to encourage and stimulate student thinking and reasoning. When students present their work and conclusions, the teacher, as a facilitator, challenges the students’ method by asking them to explain the reason behind their choice, whether they had thought of another method and if they did, why they discarded it and to also speculate the outcome had they chosen the other method. Such teacher assistance does not take away any agency from the students in determining the outcome of their learning. On the contrary, it provides an opportunity for understanding to take place (Lombard and Schneider, 2013) as the teacher would have guided the students' learning process and even provided opportunities for the cross-fertilisation of ideas during the whole class discussion. Here, the interplay between the use of questioning strategies and teacher telling comes in (Hmelo-Silver, 2004).

In an inquiry classroom, the teacher has a pivotal role in guiding students and supporting them in learning to work independently (Maaß and Artigue, 2013). But what if the students need to consult academic resources and documents? Will providing students with authentic resources (resources closer to research, as such resources guide towards answering good questions) lead to loss of student involvement? Students should be taught core science concepts and only then be provided with a variety of authentic resources, so they will be able to identify, consult and refer to the relevant resources. Although I suggest that students are provided with a several authentic resources, they should be given autonomy in the selection of resources (Rouet, 2006; Rouet et al., 2011). However, the teacher should ensure that the authentic resources are relevant to the concept being tackled. It seems to me that this would establish a compromise about the dilemma between letting the students explore and telling them the answers (Towers, 2010), which would result in striking an appropriate balance between the challenge and the learning assistance provided (Engeln, Mikelskis-Seifert and Euler, 2014).

For effective learning to take place, the teaching and learning processes need to promote understanding. Teaching for understanding requires skills in selecting, designing and presenting inviting situations to students, managing small-group work, guiding whole-class discussions and exploiting the range of students' solution strategies. It has to be acknowledged that an IBL approach requires a change in both the teachers' and the students' roles. In an IBL approach, the students are responsible for their learning and for this to happen, the teacher must possess the necessary skills that help students scaffold their learning (Hmelo-Silver et al., 2007). These skills include giving students space to think, sharing ideas, discussing, coming up with clear arguments and providing valid solutions. Furthermore, teachers should avoid providing answers outright or giving hints towards a specific answer. Refraining from judging the students' responses and providing the correct answer are also necessary. Teachers should only encourage, promote and provoke cognitive challenges (Hmelo-Silver, 2004). In other words, the teachers' role in IBL requires the teachers to be 'fully present, interested, engaged, listening, accepting – while actively avoiding committing ideas' (Foster, 2014, p.149). However, the teachers should also draw the students' attention to meaningful ideas emerging from their presentations by providing 'content knowledge on a just-in-time basis' (Hmelo-Silver et al., 2007, p.100). Orchestrating the learning episodes during the first IBL activities I implemented was not an easy task for me, as very often I found myself giving the students hints on what to do and what to look for. There were also instances where I outright pointed out an incorrect conclusion instead of challenging their ideas and conclusions. What helped me was asking colleagues to observe and provide feedback on my role during the IBL activities I implemented, and I observed my colleagues during the IBL activities they implemented and then discussed our roles and ways to improve.

Moreover, the student thinking is looked into through the skillful use of questions that prompt students to explain their reasoning, which requires the teachers to respond to students in a different way. Teachers need to change their role from a 'dispenser of knowledge to a midwife – hence, helping them deliver their own ideas' (Marcum-Dietrich, 2007, p.86), by their skillful use of questions.

2.8 The skillful use of questions

It is not enough for our students to understand concepts, if they are to be considered scientifically literate, but they also need to be able to talk science. The questions posed by teachers have been identified as a significant factor in facilitating the students' ability to talk science in the classroom (Chin, 2006). She further emphasises that this can be enabled through closed questions as well as open-ended questions. Closed questions 'tend to focus on evaluating student knowledge' (Smart and Marshall, 2013, p.251), while open-ended or divergent questions seek to elicit students' thoughts, to encourage elaboration on previous answers and also to justify their claims (Morge, 2005). From my experience, I believe that during an IBL approach, closed questions should be asked at the initiation stage, 'to encourage students to put the main idea in their own words' (Mercer and Howe, 2012, p.13). Then, pose open-ended and divergent questions while the students are carrying out the investigation to 'stimulate and guide the students thinking in a productive way' (ibid., p.14).

In an IBL environment, students also ask questions, possibly when their ideas are discordant or to request further information while reflecting on understanding. In their study, Lombard and Schneider (2013) paid particular attention, to how students refined questions. They claimed that an investigation 'does not automatically lead students to 'good' questions' (ibid., p.166). Hence, what type of questions do the students need to ask when given a situation to which they need to find a solution? Let's imagine this scenario: students are given a cylinder, a piece of wood with a rough surface and another piece of wood with a smooth surface. They are asked to see on which surface the cylinder would roll with ease. The students might be able to conclude that the cylinder rolls over the smooth surface with ease but not over the rough surface, but this would not necessarily lead to meaningful learning as students might not understand the actual concept of friction or the cause. In this scenario, the students would be doing things, but might not learn much from the activity. However, their experiential learning might allow them to make further predictions, such as which surfaces provide more friction or which surfaces are nearly frictionless, if given the opportunity to do so (with the help of the teacher being a facilitator). Concepts are more understandable when students manipulate objects and experiment for themselves (Colburn and Nguyen, 2012). This implies that if students were given the opportunity to continue to experiment with multiple objects and surfaces, they would have been possibly able to extrapolate the true meaning of friction, i.e. the resistance encountered by the objects on certain surfaces. This would therefore be a significant question, as it enables the students to learn science and not learn *about* science.

An inquiry-based setting provides the students with an opportunity to engage in discussions. During these discussions, students are given the chance to have pupil-pupil talk and teacher-pupil talk. It seems to me that these discussions in turn, will help students develop a better understanding of the concepts. The possibility of understanding the concepts better might increase the students' ability to formulate questions by sharing knowledge and discussing the questions, and also to understand which questions are appropriate and worth investigating.

As Kuhn (cited in Lombard and Schneider, 2013, p.166) puts it, good questions are those questions, which the group considers as significant and worth investigating. This highlights the importance of giving the students the opportunity to first discuss the questions they were presented with, modify them and then, conclude which questions are significant. Here, the teacher has a pivotal role in guiding students and supporting them in learning to work independently (Maaß and Artigue, 2013). It seems to me that guiding the students by asking them '*Why?*' (Why they had chosen that particular method or tools?) and '*What if?*', (What they think would have happened to the outcome had they opted for another method?) would provide the students with a good opportunity to learn to work independently. In the next section, an insight into which approaches best support IBL is provided.

2.9 Approaches to support IBL

Research on the benefits of IBL gives an inconsistent picture of the effects (Maaß and Artigue, 2013). More often than not, approaches providing some form of scaffolding, which Wood, Bruner and Ross (1976) define as a process in which teachers model or demonstrate how to solve a problem, and then step back, offering support as needed, are found more effective in bringing about learning when compared to those offering minimal guidance (Hmelo-Silver et al., 2007; Kirschner, Sweller and Clark, 2006). Inquiry-based learning environments are neither minimally guided nor unguided approaches, as they provide many forms of scaffolding. Through scaffolding, students are given opportunities to engage in complex tasks. This infers the importance of the role that teacher guidance plays. The structure and guidance teachers offer to students 'through coaching, task structuring and hints' (Hmelo-Silver et al., 2007, p.100) enable students to become problem-solvers.

To avoid the risk of misinterpreting IBL and discovery learning, I find it crucial to make this clear distinction: discovery approaches advocate minimal or unguided instruction, though the teacher gives the pupils a specific goal (Alfieri et al., 2011), while an IBL approach adheres to more thoughtful support and extensive scaffolding (see Hmelo-Silver et al., 2007) at different stages of the inquiry process. I attempt to elucidate this distinction by pointing out the following principles that underline IBL:

- Providing tasks which are challenging but achievable (Willis, 2010)
- Fostering an environment that values and fosters different ideas (Swan, 2006)
- Pushing students to think deeply by asking open-ended or divergent questions, testing their methods and questioning their answers (Hmelo-Silver et al., 2007)
- Modeling the type of questions that students need to ask themselves (ibid.)
- Cultivating active student participation, agency and responsibility throughout the lesson by working in a group and as a group, acquiring information and communicating and sharing information with the other members of the group (Schoenfeld, 2013).

These principles could, in my view, prove to be a way of enabling students to develop a critical mind by skillfully analysing, assessing and reconstructing information and not simply accepting all the arguments and conclusions they are exposed to. I believe that in classrooms that value a collaborative questioning attitude, and when teachers are able to support students in learning to ask questions, students might be in a better position to inquire.

Despite IBL being a powerful tool in developing students' problem-solving skills, uniting theory and practice, developing communicating skills and observing events from a deeper perspective (Akınoğlu and Ozkardes Tandoğan, 2007), there is still lack of it in the classrooms (Blanchard, Masserot and Holbrook, 2014). A possible reason could be the teachers' constraints and dilemmas in adopting an IBL approach. If we want to move to an active learning pedagogy, where our students become autonomous learners, the challenges the teachers face in adopting an IBL approach cannot be neglected. It has to be acknowledged that the change required in the role of the teachers in an IBL setting poses some challenges to the teachers and thus, adequate support should be provided to them. Therefore, the next section provides an insight into the challenges teachers face in adopting an IBL approach.

2.10 Challenges in adopting IBL

I was part of the PRIMAS Project (Promoting Inquiry-based learning in mathematics and science education across Europe) for two consecutive scholastic years. The aims of the PRIMAS project (http://www.primas-project.eu) were to support teachers across Europe, in integrating and applying inquiry-based learning approaches in the Mathematics and Science classrooms, with the aim that a larger number of students would consider studying these subjects after compulsory schooling and seek employment in related fields. During this project, teaching resources, professional development courses for teachers, support for teachers and support for professional development facilitators were developed. In fact, in Malta, teachers who were interested in developing such skills through the PRIMAS project were given continuous professional development (CPD), which incorporated two components: an off-the-job summer workshop, which focused on research-based IBL principles and follow-up meetings held during the year. The follow-up meetings, which were off-set by a lower workload (2 lessons a week), provided on-the-job support to share ideas, evaluate and plan IBL lessons.

During the two years of the PRIMAS Project, I have tried inquiry-based learning activities with 8 classes (a total of 170 students). I have encountered a good number of problems. Students who aced their exams in previous years were rather skeptical about this approach; a couple of students simply refused to do the activity and just got out their workbook and started working some examples. Some students even complained that since I was the teacher, I was the one who was supposed to tell them what to do and how to do it and they should just try out some questions, which I should then correct. Their parents, for whom drilling as an essential in order to pass examinations was a strongly held belief, were even more taken aback. Some parents even contacted the Head of School, complaining that I was wasting their children's time and wanted to know whether I was a newly qualified teacher and that if so, I should not have been given a good Year 11 class.

It was a completely different experience with the low-academic achieving students; at first, the groups did not work well together, some activities turned into arts and crafts while other activities were completed even though some members were clueless about what was expected from them. There were a few instances where the groups did not point out any pitfalls in what the other groups were presenting during class discussion, so that their outcome/presentation would be the best.

Holbrook and Kolodner (2000), from their experience with inquiry-based and designed based approaches to middle school science, have discovered several problems teachers face in adopting an inquiry-based approach in their classroom. The most common problems they encountered were that groups did not always work well together, competition between groups often resulted in not acknowledging mistakes and weaknesses in others' presented work, activities turned into arts and crafts and although the task was successfully completed by a group, not all its members understood the basis for its design or how 'it embodied the science' (ibid., p.223). They also encountered students who ignored or misunderstood the challenge. Having been part of the PRIMAS project and working in a group of ten teachers, the impediments we faced were similar to those identified by Holbrook and Kolodner (2000). Thus, I can say that teachers do face several constraints when implementing new approaches, some of which are external, such as curriculum and assessment practices, high-stakes examinations and lack of resources. However, it seems to me that much of the difficulty that teachers encounter when implementing new approaches to educational reform seems to be their beliefs and values about the subject, teaching and learning (Anderson, 2002).

Since in an IBL approach, students need to be engaged with the concepts they are presented with, the next section discusses the relationship between IBL and academic engagement.

2.11 IBL and academic engagement

Research has shown that when students have more autonomy in the classroom, they benefit academically (Palincsar and Herrenkohl, 2002; Gillies and Khan, 2008; Alozie et al., 2010). Throughout an IBL setting, students are given space to collectively propose, explain and challenge ideas in discussions with one another and with the teacher, which according to Kirch (2010) enhances academic benefits in science. In fact, the use of successful inquiry-based learning in science curricula has been regularly associated with increased student achievement (Schroeder et al., 2007; Schwartz *et al*., 2009) and 'greater performance on learning outcomes' (Hushman and Marley, 2015, p.373). I find it important to mention that the research I have read has also suggested that inquiry-based learning environments foster better engagement among disadvantaged students (Marx et al., 2004; Kahle et al., 2000; Scott Grabinger and Dunlap, 1995; Scruggs et al., 1993). Furthermore, IBL activities have very often been associated with promoting students' motivation (Crawford, 2000; Holbrook and Kolodner, 2000; Marx et al., 2004, Tuan et al., 2005).

If we want to improve the students' understanding of Physics concepts and increase their performance on the learning outcomes in Physics, research aimed at finding out whether the pedagogy adopted in the classrooms affects the students' academic engagement to learn and demonstrate their understanding of physics concepts is vital.

The choices teachers make, on a daily basis, play a crucial role on the effect of whether students will be academically engaged and learn (Schiefele and Csikszentmihalyi, 1995). Such choices include:

- the assessment methods adopted (Anderman and Anderman, 2010) as the students tend to engage more deeply and persist on thought-provoking problems if they find the tasks assigned to them both in class and as homework interesting. Also, Anand and Ross (1987) articulated that a task can be more effective in promoting interest if it connects a problem to students' lives;
- holding high expectations for all students, as they will be more likely to persist in pursuit of problem solutions if they feel that they are capable of solving the problem (Schunk and Zimmerman, 2006) and
- be committed to having positive relationships with the students, where the students can share their ideas without feeling self-conscious. According to Delpit (1995) and Reeve (2009), such relationships can enhance academic achievement.

2.12 Concluding Comments

This chapter presented a review of the literature about IBL and the need to learn the language of Physics as well as the role of the language of instruction in a bilingual context.

With the above research-informed understandings related to personal insights on teaching and learning through inquiry, I now move to explain the methodological approach developed and implemented for the data collection for the first cycle of this research study, and the research tools used to address the main research question guiding this study:

‘Does an inquiry-based approach enable students to construct knowledge of physics concepts among themselves and with their teacher, even when learning in a language that may not be their preferred language?’

As I came to reflect on the analysis of my data, two additional theoretical tools were further developed, that helped me make meaning of the data: Vygotsky’s work around the central role of language in learning and Lave and Wenger’s (1991) ‘communities of enquiry’ and related work. I address these ideas, and their roles for my thesis, in a ‘Theoretical Interlude’ between chapters 7 and 8.

Methodology - Cycle One

3.0 Introduction to the chapter

This chapter presents the methodological approach developed and implemented in this research study. I present my justification to why I took an interpretative approach and decided to use action research methodology to research my pedagogical approach and support my students' learning. The main research question guiding the research is then put forward. I then tackle the first cycle of the action research methodology and the research tools used to obtain insight into the learning process and its effectiveness.

This research draws on the theoretical framework presented in the literature review. It acknowledges the value of inquiry-based learning as a means of getting students to think (Mutlu, 2020) and reflect on physical phenomena, promoting effective learning in the process (Verawati, Hikmawati and Proyogi, 2020). It also endorses the belief that verbal interactions and exchanges with others support the learning process (Stamovlasis, Dimos, & Tsaparlis, 2006), enabling my secondary students to build knowledge and understanding of physics concepts. Thus, during the study underpinning this thesis, I wanted to follow Foucault's idea of power; to circulate power and to exist in the action and in the discourse of my students. I wanted to create an academic space where my students could 'act and interact according to their own wishes' (Oral, 2013, p.107). This does not mean that they could engage in off-task activities, as I still monitored the classroom. Thus, I can say that I tried to distribute power in the classroom, as I afforded the students space to think, share their ideas, work at their own pace to carry out the investigation and also use their preferred language, however, the students still had to be on-task in order to complete the task. In other words, I was distributing some of my power while still maintaining the balance, in order to fulfil professional responsibilities. This is the opposite of classrooms where teachers do not allow 'overlapping talking' but instead allow students to talk only to respond to the teachers' questions, to talk one at a time and restrict 'learners to a responding role' (Oral, 2013, p.97). These are examples of when teachers occupy a role of power, by controlling the content and the 'direction of classwork' (ibid., p.97).

This study also considers the reality of teaching in Malta, which is bilingual (Camilleri Grima, 2013), and how students possess different levels of proficiency of the English language (Schriha and Vassallo, 2001), which is the mode of assessment of Physics.

The aim of this research was to gain a profound understanding of how my students construct physics knowledge with my support as a facilitator of learning (Aina, 2017). Another aim was to improve the quality of learning during the discussions taking place in my class without my interventions. Thus, I believed that this research required a qualitative methodological approach which enabled me, as a researcher, to seek tacit knowledge to understand phenomena (Stake, 2005). Qualitative research is concerned with how people act and typically interact (Taylor, Bogdan and DeVault, 2016). Since I was researching my professional practice and trying to work out the pedagogical approaches, which would help my students to overcome their struggles in learning Physics, I opted to take on action research. Action research involves studies carried out in the course of an activity or occupation, typically in the field of education, to improve the methods and approach of those involved. Thus, through action research, I wanted to be a teacher-researcher willing to look critically at my own teaching to improve my professional practice which would be for the benefit of my students (Feldman and Minstrell, 2000).

3.1 My interests

The impetus for this study was in response to my desire to tackle the students' difficulty with learning Physics. I noticed that my students were struggling with understanding physics concepts. I intentionally wanted to introduce changes in learning approaches that I was promoting in my class. I wanted to shift my teaching away from the traditional learning approaches, which tend to consider students as passive receivers of information (Darsih, 2018). The methods that I was using prior to this study mainly involved 'lecturing, note-taking, and memorising information for later recognition or reproduction' (MacLellan and Soden, 2004, p.254). I had wanted to promote student-centred learning and had tried to implement some inquiry-based learning activities. I had come to know about it as I participated in a Primas Project, which promoted this approach. My desire was thus to change my pedagogy to an effective student-centred approach. It arose from my belief that an inquiry-based approach promotes better understanding of concepts as ‘scientific phenomena are constructed through social discourse’ (Berland and Reiser, 2009, p.28). Consequently, I was convinced that inquiry would enhance my students’ construction of knowledge. I also believed that with more inquiry, I would also support student talk, enabling my students to also learn to talk physics and use the appropriate language of physics to express themselves well when dealing with physics concepts.

This study thus consisted of action research where I wanted to research the effectiveness of changing my teaching approach through introducing more inquiry-based learning and analysing its effect on the students’ understanding of physics and their ability to talk physics. Consequently, this study required careful attention to data collection to interpret and analyse my practice, and the consequent learning experience of my students.

3.2 Developing the research questions

The methodology adopted in the study aimed at providing insights into the impact of structured and guided inquiry-based learning activities on my students’ learning in Physics. The study focused on using the data collected to derive conclusions about the phenomenon of interest, that is, whether using more inquiry-based learning, with more space for students’ discussions, would promote better understanding of Physics, while also developing the students’ proficiency in talking physics and in using correct scientific language to express their understanding. This approach was selected as in an inquiry-based environment, students are usually encouraged to use spoken language to present their ideas as clearly and as unequivocally as possible (Fang, Lamme and Pringle, 2010), to elaborate their ideas so others understand what they mean, to create meaning together and to make connections between everyday phenomena and scientific construction of how the world works (Krajcik and Czerniak, 2018).

The research question with which I started this study was the following:

‘Does an inquiry-based approach enable students to construct knowledge of physics concepts among themselves and with their teacher, even when learning in a language that may not be their preferred language?’

3.3 Interpretive Approach

Slevitch (2011) explains that ontology can be defined as ‘the study of reality or things that comprise reality’ (p.74) and epistemology as ‘a theory of knowledge concerned with the nature and the scope of knowledge’ (p.74). She further explains that ‘ontology defines epistemology, which in turn defines methodology, which then determines applied methods’ (p.75). Since in my study, I wanted to acquire a better understanding of how I could help my students overcome their struggles when learning Physics in a language that might not be their preferred language, I concluded that adopting a qualitative approach would be the best option. I was actually looking at the social reality of my classroom, that first language Maltese speakers were experiencing difficulty in learning Physics in their second language (my ontology), but this is not fully knowable since knowing it depends on communication and then interpretation of that. Thus, my research followed the epistemological premise that as a researcher, I could only offer my interpretations of the phenomenon I was studying (Guba and Lincoln, 1994). Therefore, this research adopted an interpretative approach. A different researcher might not only elicit different responses from the students, but interpret/notice them slightly differently, though perhaps in equally valid ways. Working across two languages, as well as the scientific register, exacerbates the problem of knowing the reality, since some of what is expressed will have limited accuracy.

This case study adopted an interpretive approach. Interpretive research has gained popularity in education research as it has far-reaching consequences for curriculum and pedagogy (Howe, 1998). The interpretative approach views reality as socially constructed or made meaningful through actors’ understanding of events (Putnam and Banghart, 2017). In interpretive research approach, the researcher collects the data, and through analysis, tries to derive patterns from the observed data about the phenomenon of interest (Bhattacherjee, 2012). One advantage of the interpretive approach is that the data collection and analysis can proceed simultaneously (Smith, 2004). The analysis and evaluations obtained enable the researcher to correct any flaws in the research tools adopted before further data are collected.

As a researcher and the teacher, I interacted closely with the research participants (my students), making me also an active participant and part of the data collection instruments. It thus required me, as the researcher, to be aware of my existing personal biases so that I could extract information in a way which limits bias in presenting 'a fair and accurate portrayal of the phenomena' (Bhattacherjee, 2012, p.106). Careful attention was paid to choosing the sample of the respondents, as the participants needed to fit the phenomena studied (Elbardan and Rashwan Kholeif, 2017). The sample for this cycle was a group of students in a class to which I taught Physics and involved: a foreign student who, although understood Maltese, communicated only in English, and three first language Maltese speakers of different levels of proficiency and preference in English. These students (aged between 13 and 14 years) were in their third year at secondary school and in their first year of learning Physics.

3.4 Action Research

The main design of this study was action research, which falls within the interpretive approach. Action research is a means through which practitioners study their own institutions, making it 'one powerful tool for improving the quality of teaching and learning within a school community' (Tillotson, 2000, p.32). Action research is not carried out on other people, but conducted by individuals on their own work, either to help them improve what they do or how they work for others (Burns, 2015). Action researchers analyse data to improve their own practice (Koshy et al., 2011). It is a systematic reflective study of one's actions and the effects of these actions in their workplace (Riel, 2016). This means that in schools, teachers can develop 'hypotheses about their teaching' (Costello, 2011, p.20) and use it to enhance their teaching.

Action research involves a cyclical process of diagnosing a problem and reflecting on practice: planning an action to tackle the problem; implementing the planned action; reflecting on the insights obtained from the implemented action;

suggesting modifications and improvements to the action implemented and taking further action (Riel, 2016). This enables the cycle to be repeated with the modified action plan to address the problem better and gain better insight with each cycle. The literature suggests that the 'entire action research is traversed at least twice' (Bhattacherjee, 2012, p.108) so that the insights obtained from the first cycle can be implemented in the second cycle, to see whether the problem has been successfully resolved.

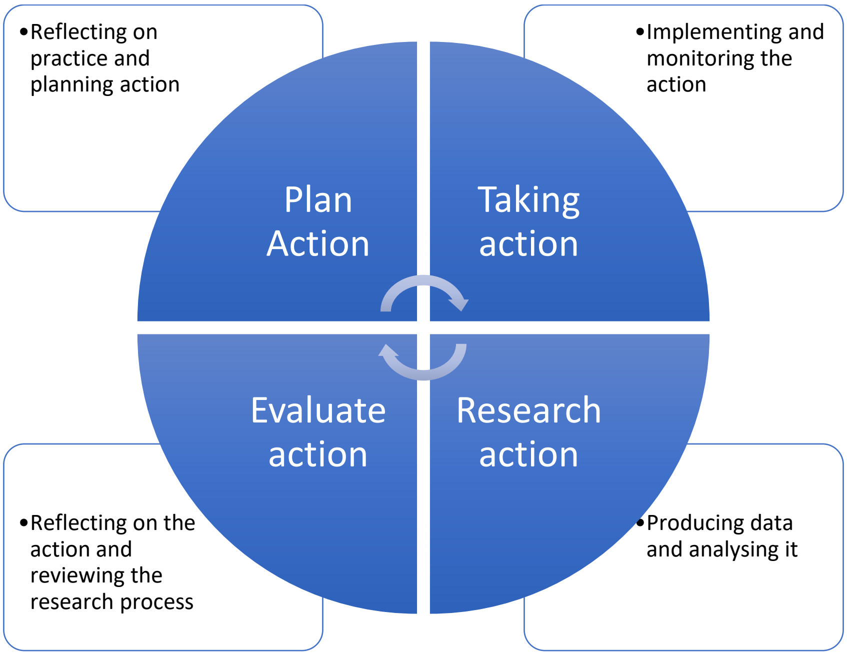


Figure 3.1: Cyclical process of research (Cohen et al., 1993)

Research tools used in action research are generally common to the qualitative research paradigm, including document collection such as field notes, audio recordings of lessons, students' work and analysis, partially structured interviews, and unstructured interviews and focus groups (Johnson, 2012). Consequently, more than one method for collecting data is usually adopted. The pluralism of data collection methods can provide thorough understanding of the research phenomena (Devetak et al., 2010). Interpretive research tends to rely mainly on qualitative data. However, quantitative data may be included to provide a clearer understanding of the focus of the study. Generally, quantitative data used tend to be tabulations of the codes used for the content analysis, to see and note their frequencies (Bhattacherjee, 2012). Such data are, however, not statistically analysed. The methods adopted for this study included: field notes from lessons at the end of each IBL activity; audio-taped class conversations of each IBL activity implemented which were then transcribed word for word; and semi-structured one-to-one interviews. The combination of multiple methods, referred to as triangulation, adds rigour and breadth to any research (Denzin and Lincoln, 2005), as evidence is gathered from a number of sources. This evidence helps the researcher acquire a broad picture of the changes occurring and the changes that are required.

For my study, the fundamental justification for choosing action research was that I was a teacher and I was unhappy with my students' depth of learning and understanding of physics concepts, as well as their limitations in talking about the concepts learned in a proficient manner and using proper scientific talk. I was thus researching my own pedagogy and considering in what ways I could improve my teaching to help my students. I was taking what Riel (2016) calls 'a living and learning stance to teaching'. The aim of this action research was to influence my practice as I collected data and obtained insights into my students' learning. I was thus making research-informed changes to my practice with the intention of improving the learning of my students.

3.5 Setting and participants

This study took place in a Maltese State School located in the northern region of the island of Malta. Since this is not the only school in the northern region, the catchment area included towns both from the northern region as well as from the central/north region. There is a primary school in every town and village in Malta. This is not the case for secondary schools. The secondary school system in this country divides its secondary institutions into two different schools: the Middle schools, which cater for the first two years of secondary schooling (Years 7 and 8; 12 and 13-year-olds) and the Senior schools, which cater for the last three years of secondary schooling (Years 9, 10 and 11; 14 to 16-year-olds). The school in which this study was carried out is one of the only two schools in Malta which caters for both middle and senior years under one administration.

This research was carried out when the students were in Year 9 (the first year of senior school). The class consisted of 16 students; a mix of male and female students. This was the students' first year of learning Physics, which is still a compulsory subject in state schools. Being the teacher and the researcher enabled me to observe which students got on well together and worked well as a group. The sample for Cycle One of this study was a group of four boys who worked well together but varied in terms of their level of proficiency and preference in the English language. They were used to working in a group together and this did not disrupt their class format. I decided to focus on this group of students after taking into consideration their performance in half-yearly and annual English examinations as well as my knowledge of their ability to discuss in English during the Physics lessons during the first two months of Year 9 when I taught them. My intention was to include students with different levels of English proficiency as well as different levels of academic achievement.

The four students participating in Cycle One of this study were Yuri, Noel, Robert and Matthew. (In Cycle Two, these students were joined by Keith)

Yuri was a foreigner, the father being Serbian and his mother British. He was fluent in both Serbian and English. Since he had been residing in Malta for seven years, he also understood Maltese but struggled to speak it. He obtained good grades in all examinations assessed in English and passed the Maltese examination. Yuri was friendly, easy-going and got on well with his peers. He was confident and able to discuss and share ideas during the Physics lessons.

Noel was a first-language Maltese speaker. He was confident in discussing both in English as well as in Maltese (thus having English proficiency) and had obtained good grades in his English examinations (good achiever) as well as in other subjects which are assessed in English. Noel was also friendly, easy-going and got on well with his peers. Similar to Yuri, Noel was confident and able to discuss and share ideas during the Physics lessons.

Robert and Matthew were also first-language Maltese speakers. These two students did not perform well, either in English or in other exams assessed in English (students with low English proficiency and low achievement). Robert was also friendly, and got on well with his peers, while Matthew was more of a quiet type. The input by Robert and Matthew during the Physics lessons was often limited to a few words in English. With regards to Robert, this was possibly due to limited proficiency in the English language while in Matthew's situation, I believe it was a combination of being the quiet type with limited proficiency in the English language. However, they were able to discuss and share their ideas in Maltese, Robert more often than Matthew.

Keith was also a first-language Maltese speaker. He was confident in discussing both in English as well as in Maltese (thus having English proficiency) and had obtained good grades in his English examinations (good achiever) as well as in other subjects which are assessed in English. Keith was also friendly, easy-going and got on well with his peers. Similar to Yuri and Noel, Keith was confident and able to discuss and share ideas during the Physics lessons.

3.6 My positionality in the study

The positionality of the researcher in relationship to the setting and participants is important in all research studies (Herr and Anderson, 2015). In action research studies, the extremes of the continuum of the positionality of the researcher are situated between the insider and the outsider. An insider studies own self-practice while the outsider studies the insider(s). Herr and Anderson (2015) explain that the positionality of the researcher 'does not fall out in neat categories' (p.48) and can shift throughout the study. This means that the positionality of the researcher can be fluid (Thompson and Gunter, 2011). As a practitioner-researcher, I wanted to generate knowledge of my practice. I wanted to study the outcomes of my change in pedagogy in my own setting. Being the teacher whose own pedagogy I was researching, and my tacit knowledge of the setting and the participants made me an insider (Herr and Anderson, 2015). My adult status and my education level together with this research being a university-based academic research made me an outsider (ibid). Although this made my positionality as one of an insider-outsider, I considered myself as more of an insider due to my knowledge of the setting and the participants, and by taking this positionality, I aimed to learn how to reflect on my pedagogy and what I learnt in the process.

Being more of an insider researcher had pros and cons for my research. As an insider, I had 'better initial understanding of the social setting' (Mercer, 2007, p.6) because I knew the context. As an insider, the students knew me as a teacher in the school for more than two years and as their teacher for a few months. Mercer

(2007) explains that this position is like a double-edged sword: on one hand, being an insider can be considered as a fact that might 'engender a greater level of candour than would otherwise be the case' (ibid., p.7) which might result in a more 'accurate portrayal' (ibid., p.7) of the data, while on the other hand, the insider might be more likely to take things for granted, which might result in the data becoming thinner. Therefore, I needed to be careful not to lose what I gained as an insider researcher in terms of my 'extensive and intimate knowledge of the culture' (Hawkins, 1990, p. 417) as a result of my myopia and my 'inability to make the familiar strange' (ibid., p. 417). There were also some ethical implications of being an insider. These are discussed in the section below.

3.7 Ethics

As the researcher, I gained university ethics approval from IOE before the activities were carried out, which can be found in Appendix 1. Permission to carry out this study in a Maltese state school was obtained from the MFED Research Ethics Committee (MREC), within the Directorate for Research, Lifelong Learning and Employability at the Ministry for Education. Permission was also sought from the Head of school. Written consent was sought from the parents/guardians. Since I was an insider, I was concerned in getting genuinely voluntary informed consent as I was in a position of power. Thus, prior to asking for consent, I also verbally explained to my students the reasons for which they were asked to participate in this study. The consent form sent to the parents can be found in Appendix 2. The participants and their parents/guardians were informed about the 'guarantees of confidentiality, anonymity and non-traceability in the research' (Cohen et al., 2011, p.318). With regards to confidentiality, the participants, as well as their parents/guardians were assured that only the researcher would have access to the raw data, that is, the audio-recordings of the lessons. In fact, the recordings were encrypted on my laptop. I also explained that since I was the researcher, the guarantees of anonymity and non-traceability were only applicable to those reading the research as their real names would not be used, and that they would be referred to by pseudonyms. This was intended as an additional safeguard to protect the anonymity of the participants (Smith and Firth, 2011).

As an insider researcher, I was also concerned about the use of professional responsibilities (class time) for my research. I tried to avoid allowing a research-interesting discussion such as when they were discussing that a person who sweats more burns off more calories to continue, whereas as a teacher I might have drawn the class back together at that point.

Having described the ethical issues taken into consideration for this study, it is now time to move onto discussing the data collection underpinning this study.

3.8 Method of data collection used

In order to evaluate the impact of my new pedagogy, and to analyse the type of exchanges which took place during the lessons, the main data collection tools which I used included self-reflections, audio-recordings of the lessons, and interviews with the students.

- Self-reflections about the lessons at the end of each IBL activity (focusing mainly on the type of questions I asked: to elicit what the students think, to elaborate on previous answers, to guide and help students construct their own meaning (Chin, 2006));
- Three audio-taped class conversations which included the introduction of each activity, any whole class discussions that took place as well as the conversations among the target group during group work, which were then transcribed word for word; and
- Semi-structured interviews which consisted of fourteen questions.

Having described the research tools underpinning this study, it is now time to discuss the categories planned to analyse the students' discourse.

3.9 Planned categories to analyse the data

The primary focus of this cycle was to support my students' learning process to understand physics concepts and to enable them to "talk physics" by teaching them the language of physics. The audio-recordings obtained during the three activities were transcribed.

I organized the analysis of this data based on the use of content analysis. Content analysis is defined as a method of studying and analysing communication in an objective and quantitative manner, for the purpose of measuring variables (Prasad, 2008). I deemed content analysis to be the best tool to analyse the data gathered during this cycle as the aim was to look at the students' discourse to identify the purpose of their contributions to the discussion in an inquiry-based learning setting. My preferences were to use deductive content analysis, allowing me to set predetermined categories based on aspects of inquiry-based learning in advance. This allowed my findings to be related to existing literature based on aspects of inquiry-based learning, such as, students attempting to make connections between previously acquired knowledge and their observations as well as attempting to explain their observations based on evidence (Blanchard, Masserot and Holbrook, 2014). The planned categories used to look at the students' input are reflected in Table 3.0, with examples of each. I could then map connections in the data to those specific categories. This provided structure to my analysis.

The analysis aimed to provide me with insights about different aspects of inquiry-based learning: how much the students asked questions and of what type; how often the students engaged in explaining their observations and assertions; made critical statements about physics content being considered; identified connections between previously acquired knowledge and their observations; expressed patterns, made observations about physics phenomena; and drew conclusions. In the case of language, I looked at how much the students used scientific terms accurately.

Table 3.0 below illustrates examples of how the categories planned were used for the analysis of the students' discourse during these three IBL activities.

Table 3.0: *Categories used for content analysis in Cycle One with examples used in analysis*

Category	Example
Asked/proposed questions (any questions put forward by the students)	Noel: Maybe the bulb was stronger?
The type of question they posed (What? How? Why?)	No examples were found
Explained things	Teacher: Oil always floats on water. Can you explain this in terms of density? *Noel: mmmm te density of oil is less than that of*

	water.
Made critical statements	Yuri: …. the masses are different, so mass per 1 volume is different, so density of them is different. Those with a density bigger than water will sink, the others will float.
Made connections between previously acquired knowledge and their observations	Robert: Maple liquid went to the bottom. Letter C is the largest number, so we think that maple has the largest density, greater than that of water.
Expressed patterns	Noel: Oil always floats.
Observational statement	Robert: House A got a higher temperature.
Suggested conclusions	Yuri: Maybe because House B was bigger, it needed more time to get so hot?
Made use of scientific terms/language correctly	Yuri: … Those with a density bigger than water will sink, the others will float.

*Context is in italics

Having described the research tools underpinning this study, it is now time to discuss the challenges met to implement the research.

3.10 Challenges to implement the research

Although action research was considered as the most appropriate methodology for this study, there were some practical problems encountered in implementing the study. These issues had to be considered at the beginning. These logistical challenges were in line with what Cohen et al. (2011) pointed out:

i) framing an economical way as regards the time spent on gathering and analysing data for a teacher along a normal workload. The implementation of the first activity was postponed multiple times as I wanted the students who were selected as the target group to be all present during each activity. This would have resulted in data gathering for this cycle not to be complete within one scholastic.

ii) since this study involved 2 cycles, research might not be completed within one scholastic year;

iii) Being a small-scale investigation carried out by a teacher, my research,' though provided new insights, these insights were about one small group only and may not necessarily apply to the rest of the class. Thus, since the findings were limited to the target group and me within my institution, it might only provide minimal generalisations, even if there were deep insights obtained which may lead to considerations and reflection about teaching and learning in Physics in general. Had I carried out this investigation with another group from another class, I would have been able to compare the findings of this particular group, with the findings of the other group from a different class. The second group could have provided better insights for pedagogical implications.

As the researcher, I reflected on these challenges to find ways to address them and consider how best to find solutions. Request for unpaid study leave, to focus on my studies, mainly to carry out the analysis of this cycle was discussed with the Head of School and the Director of Education. Both had verbally agreed that they would find no objection when the time arose. Later on, it was suggested I work on reduced hours due to the lack of teachers of Mathematics and Physics and also for it to be easier for me to carry out the interviews with my students. The first cycle was done in one year (during the scholastic year 2016-2017) and the second cycle was done in the following two years (during the scholastic years 2017-2018 and 2018-2019). Thus, since the data collection process was not to be done within one scholastic year, permission from the Head of School to teach the same students during the following year was sought. This was approved and in fact, the following year I had two classes at Form 4 level (Year 10), one of which was the class in which I had carried out the first cycle of this study.

With a focus on social learning, Vygotsky (1987) argues that students' learning is mediated by their language and their ability to grasp the meaning of others' language. The students' ability to demonstrate their learning is also limited not only by their language, but also by their lack of ability to put their thought to word, thus evidencing of this is also constrained by the researcher's noticing and opportunity to observe for language is not only one research focus, but also the means by which the researcher evidences the students' ability to co-construct knowledge.

Engaging in an inquiry-based learning approach requires the students to work as a community of learners (Burton, 2023), where the students will have shared goals, and collaborate and connect with one another to share and co-construct knowledge. Trying to develop a community of learners within my classroom not only required providing the students with opportunities to talk, but also ensuring the development of dialogic language over time, with my support. It is important to point out that when the focus is only on what is said, although evidencing learning might be more clearly evidenced in a social setting where students are vebalising their thought, it is still difficult to evidence who is learning what and in/for what context, because certain students might appear quiet and though this does not mean that they are less involved or learning less, it is difficult to evidence their learning, despite there might be some indicators, such as participating in carrying out the activity. Thus, I would have captured only a small subset of relevant data.

3.11 Validity and Thrustworthiness of this study

Several terms have been suggested to 'describe criteria for good action research' (Herr and Anderson, 2015, p.63). Like all researchers, action researchers are interested in whether their research is valid and trustworthy. Herr and Anderson (2105) further explained that the validity of action research can be either internal, external or both. They define internal validity as 'the trustworthiness of inferences drawn from data' (p.63) and external validity as to 'how well these inferences genralise to a larger population or are transferable to other contexts' (p.63). The following 5 criteria for validity: outcome; process; democratic; catalytic; and dialogic have been linked to the goals of action research.

Research is valid in terms of outcome validity not only when a solution is found to the problem investigated, but also when new set of research questions are generated, as this leads to the 'spiralling dynamic that characterize the process of most action research' (p.68). In my first research question, I attempted to find a solution to the problem of helping students understand physics concepts as they were struggling to do so. This lead to a new research question: whether allowing my students to use their preferred language facilitated their understanding. Thus, my research can be considered as valid in terms of outcome validity. Since my research generated new knowledge, as it helped me as a practitioner to grow professionally and also helped my students in understanding the physics concepts better, it can also be considered as valid it terms of catalytic validity. My research further generated knowledge about teaching and learning Physics in a bilingual context, and thus can be considered valid also in terms of dialogic and process validity. Moreover, the results were relevant to the local setting, making my research valid also in terms of democratic validity.

3.12 Chapter Summary

This chapter started by presenting the methodological approach which is based on an interpretive approach to research and action research. I explained my positionality in the study as both teacher to my students and researcher. The data collection process and the research tools adopted for the data collection process were also discussed. Issues of validity, ethical clearance and logistics for implementing the whole action-research study were also presented.

The next chapter thus provides the detailed descriptions of the methodology of Cycle One, the inquiry activities implemented with the students and the data collected. It also presents the analysis carried out for each of the activities implemented as well as the insights obtained. The main findings of this cycle and their implication to Cycle Two of the research are presented.

Analysis
Cycle One

4.0 Cycle One

This chapter describes the specific research question adopted for Cycle One. It describes the inquiry-based activities that I implemented in class with my students and the research methodology used as part of the data collection process. I also explain how I coded the data transcripts collected and carried out the analysis of the data. The detailed analysis and the main outcomes of this phase of the research are presented. The last part of the chapter highlights the research key findings and their main implications to my practice and to the next cycle of the research.

4.1 The focus of the first cycle of this action research

In the first cycle of my research I wanted to focus on improving the quality of my pedagogical approach to introduce physics concepts in class. I wanted to move away from traditional teacher-centred approaches to student-centred ones by implementing a number of inquiry-based learning activities. The main aim of this first cycle was to see how the students interacted with the new content and in discussions during inquiry-based activities. I wanted to see whether they would engage more in discussions and increase the language interactions taking place during the learning process. I wanted to focus on the part of my research question which referred to the use of inquiry-based learning. I was aware of my intention to also consider the language of instruction. However, at this point, I thought that I should stick to the language policy in state schools which insisted on the strict use of the English language when teaching Physics. At the time that I was carrying out this phase of the research, the Education Officer for Physics from the Ministry of Education insisted that we teach Physics strictly in the English language. I thus had very limited room to maneuver with respect to the language of instruction. So, while I had to stick to the strict use of the English language, I tried to highlight the language used to describe concepts and explain processes in formal Physics. The specific research question which I wanted to tackle in Cycle One was the following:

‘Does an inquiry-based approach enable students to construct knowledge of physics concepts among themselves and with their teacher, even when learning in a language that may not be their preferred language?’

So, besides introducing inquiry-based learning, I made an extra effort to introduce my students to the official English language used in Physics. During this cycle, the students were encouraged to use the English language only. I, as their teacher, also spoke in English to expose the students to the language used in formal and informal assessments and to also increase the English proficiency of the first language Maltese speakers while talking and writing Physics.

4.2 Research design and implementation of Cycle One

The first step in my research design involved deciding the type of inquiry-based learning to introduce in my teaching. In any of the types of inquiries, students need to engage with the concept or context they are presented with, explore together, explain their observations, elaborate on their observations as well as on their previously acquired knowledge to draw a conclusion. Since my students lacked confidence in inquiry-based work, I decided that a semi-guided inquiry would be the best adapted approach. Because in this IBL activity I aimed to promote more discussion and scientific talk about scientific phenomena, I felt that this would enable me, as the teacher and the researcher, to obtain insights into the students' ability to engage in such an approach, and into how much they could engage in the social construction of knowledge. I also felt that it would map out the amount of guidance my students needed to reach the desired learning outcome.

The first cycle involved the implementation of 3 inquiry-based learning activities:

- one guided-inquiry activity on the topic of “Heat Losses”;
- one structured-inquiry activity on the topic of “Density”; and
- one follow-up lesson on the topic of Density.

Each of these three activities were planned to be carried out over one double lesson, that is, over 80 minutes (two consecutive lessons of 40 minutes each). These activities were different from the practical work that the students were usually expected to carry out as part of their formal assessment. During experimental work, the class is usually divided in two to ensure a lower student-teacher ratio. During these sessions the students carried out practical work which involved an experiment under controlled conditions to confirm a known physics concept. The process of the investigation was based on observations, recording data, and analysing the results to compose an explanation. The inquiry activities took place during practical sessions, and consequently in a laboratory. During these activities, the students worked in four groups where each group was placed at a large desk where they could discuss and plan the activity, carry it out, discuss their results and draw their conclusions. As their teacher, I stood in the middle of the groups at the beginning of each activity to reach out to every group. During the activities, I went around the desks to assist and guide the students when the need arose.

The students taking part in Cycle One were representative of a Year 9 Physics class in a state school and included:

- one foreign student who understood Maltese but communicated only in English;
- three first language Maltese speakers of different levels of proficiency and preference in English.

The activities carried out in Cycle One were audio recorded. Audio recordings of the activities were transcribed word for word by the researcher. Non-verbal gestures and my interventions to guide and help students construct their own meaning were also noted as field notes. Ethical issues for this study were also taken into consideration and are presented in the section 3.7

I carried out the activities over a period of one scholastic year, between September 2016 – May 2017 as follows: 1^{st} activity in mid-January, 2^{nd} activity in mid-February and the 3^{rd} activity in mid-March. The data sources included:

- ***Field notes from lessons*** at the end of each IBL activity (focusing mainly on the type of questions I asked: to elicit what the students think, to elaborate on previous answers, to guide and help students construct their own meaning (Chin, 2006))

- ***Three audio-taped class conversations*** which included the introduction of each activity, any whole class discussions that took place as well as the conversations among the target group during group work, which were then transcribed word for word.

4.3 Design and implementation of the first inquiry-based activity

The first activity involved a semi-guided IBL activity on the topic of heat losses. This IBL activity, sought to map out the amount of guidance my students needed to reach the desired learning outcome, i.e. be able to discuss the increase in temperature in relation to heat transfers. It also intended to provide me with a picture of the students' ability to engage in such an approach.

The characteristics of IBL that I tried to implement were based on the Five E's model of inquiry (Bybee, 2002; Duran and Duran, 2004): 1) engagement (students engage in planning how to carry out the investigation, making sense of their observations/data collected, ask questions seeking clarifications); 2) exploration (plan and carry out the investigation); 3) explanation (students attempt to explain their observation); 4) elaboration (students elaborate on each other's contributions to draw conclusions from the context they are engaging with) and 5) evaluation (the students' understanding is assessed). The aims of this activity were to expose the students to a different approach to learning Physics, and for me as their teacher, to obtain insight of whether changing my pedagogy to an IBL approach would enable my students to understand physics concepts better and, also about the students' needs during an IBL setting.

The inquiry-based learning activity was designed in the stages of the 5E model:

- ***Engagement:*** At the beginning of this activity, the students were presented with two different model houses and told "*We will be investigating whether heat losses in the model houses are different and which factors influence these heat losses*". The students were provided with time and space to consider the two different houses and share their opinions about which one would lose more heat;
- ***Exploration:*** This part of the inquiry involved a practical example. The main reason for which I chose it as the first activity of this cycle was to promote more discussion and scientific talk about applied phenomena, an approach which was different to the way of learning that they were used

to. The students were divided into two groups. Each group was given two model houses made out of identical material. One house had one door and one window while the other house had one door, two windows and a higher ceiling. The source for heating the model houses was a light bulb placed inside the house. The students were also given two thermometers and a stopwatch. The students were told that they first had to monitor the rise in temperature with all apertures closed and then the decrease in temperature with all apertures open.

- ***Explanation:*** The students were provided with a worksheet where they had to note down their observations and draw their conclusions about the heat losses from the two model houses (Appendix 3). The students were encouraged to talk and discuss in their group and to arrive at their own conclusions. It was up to the students to realise that either the changes in temperature had to be recorded at regular intervals or to note the time taken until the temperature in both houses stopped increasing to be able to note any patterns and draw conclusions. The students had already been taught in previous lessons that heat transfers from one object to another by conduction in solids, by convection in liquids and gases and by radiation.
- ***Elaboration:*** This part of the inquiry was intended to include a discussion of the importance of the design of houses and heat losses through conduction and convection.
- ***Evaluation:*** At this stage, I planned to elicit a discussion about the implications of the designs to cost of heating homes as well as to the environmental impact.

This activity was mainly oriented towards mastering factual content by applying the content learned to a context. This was due to my intention being that of changing my pedagogy to help my students understand physics concepts better rather than raising questions and solving problems. I still considered it as an IBL activity and not the typical experiment/practical work which is intended to confirm known content. As an IBL, it invited he students to investigate the phenomenon of heat losses through making direct observations, recording data (temperature and time), recording the results, and analysing them to draw conclusion (Wilcox and Lewandowski, 2016). Though the students were not guided in the worksheet to explain what was happening in terms of convection currents in both model houses, I expected them to do so. In other words, I expected the students to be able to make connections between their observations and the theory of heat transfer through air that they were previously taught. Although I was open to explanations using everyday language, I also expected the students to make use of the appropriate scientific terms, such as convection currents and heat losses, which were learnt in previous lessons.

4.3.1 Analysis of the first actiivty

This section provides an analysis of the implementation of the first activity. Kolb's cycle of reflection was used to analyse the students' experience and my experience of the IBL activity. It also guided my reflections on the experience of teaching through IBL, improving my practice to promote better learning among my students.

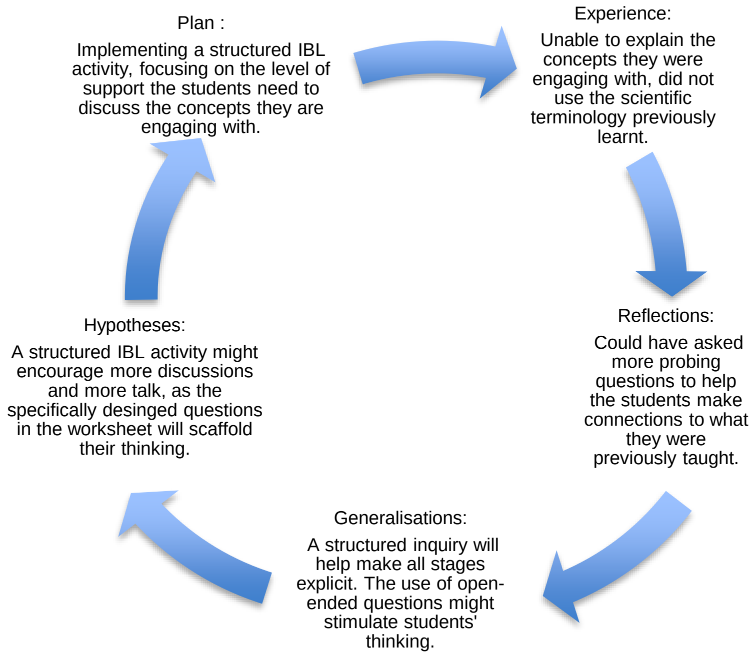


Figure 4.1: Research design following Kolb's cycle of reflection – Activity 1

By first considering the IBL activity experienced, it can be noted that the students did not talk much during the activity. In fact, there was perfect silence except for the instances when they had to record the temperature. These few contributions were mainly made until the students agreed to record the temperature of each house every minute. Though the students were encouraged to write down an explanation for what they had noted about the temperatures in both houses, they failed to discuss as a group. Thus, I as their teacher had to initiate the discussion. This was rather disappointing to me, but also an eye opener that organizing an investigation was not enough to elicit student discussion and reflection.

I also noted that the main students' contributions took place during the last stage of the activity, the plenary, where we discussed the results of the investigation together as a class. I could only carry out the analysis of the transcripts of the audio-recordings. The categories planned for the analysis of the students' discourse turned out to be useful only during the plenary section of the first activity of this cycle. The frequency of each category and the category assigned to each contribution are presented in Tables 4.0 and 4.1.

Table 4.0: *Frequencies of categories – Activity 1*

Category	Frequency of significant students' contributions
Asked/proposed questions (any questions put forward by the students)	2
The type of question they posed (What? How? Why?)	0
Explained things	3
Made critical statements	0
Made connections between previously acquired knowledge and their observations	0
Expressed patterns	0
Observational statement	1
Suggested conclusions	1
Made use of scientific terms/language correctly	0
Total	**7**

Looking at extract from the plenary part of this activity presented in Table 4.1, it can be noted that the only contribution put forward by Yuri was assigned more than one code: "*Maybe because House B was bigger, it needed more time to get so hot?*" Here Yuri attempted to explain why the temperature in House B took longer to increase but was unsure whether his suggested conclusion was correct.

Table 4.1: *Coding of contributions at the plenary stage – Activity 1*

Participant	Utterance	Code assigned
Tchr	What did you observe?	-------------------------------------
Robert	House A got a higher temperature.	Observational statement
Tchr	Can you explain why the temperature in House A was higher than that of House B?	-------------------------------------
Noel	Maybe the bulb was stronger?	Asked questions

Tchr	What do you mean by stronger?	-------------------------------------
Noel	It had more power.	Explained things
Tchr	What do you mean by 'more power'?	-------------------------------------
Noel	It got hotter faster.	Explained things
Tchr	If I tell you that both bulbs were similar, that is, they gave out the same amount of heat, can you now give another reason why the temperature was different?	-------------------------------------
Noel	Mmmmm (blank face)	-------------------------------------
Tchr	Can someone else explain this?	-------------------------------------
Yuri	Maybe because House B was bigger, it needed more time to get so hot?	Explained things + Asked questions + suggested conclusions
Tchr	Can someone else give a different explanation?	-------------------------------------
No response.		

The discussion that took place during the plenary stage of this activity, which can be found in Appendix 4, shows that despite the fact that the concepts of conduction, convection, radiation and heat losses had already been explained and taught to the students in previous lessons, they were only able to conclude that the temperature took longer to rise in the house with the higher ceiling. Throughout the discussion between myself and the students, it is noted that the students were able to observe some patterns, but they were only able to explain that because House B was bigger, it needed more time to get as hot as House A. Thus, they were unable to make connections with the content taught in the previous lessons and were unable to explain the concept they were engaging with. In fact, most of the talk was initiated by myself, as their facilitator/challenger, and the scientific talk was also promoted by me, as can be seen in Table 4.1.

On analysing this experience, I concluded that I did not manage to implement inquiry-based learning in the way that I wanted to. I realised that my interventions were not enough to promote discussions and exchanges among the students. Reflecting on the activity and my performance, I can identify important mistakes:

- ***I could have promoted more talk and discussion during groupwork:*** The students were not used to working together in groups, but to conduct experiments by simply following instructions provided. I feel that I did not make it clear enough to the students that they were expected to discuss their work during groupwork and that I was expecting them to discuss their observations together. This could probably have been the reason why there was barely any talk during the exploration phase. I should have gone around the groups and asked them to explain their thinking and the decisions that they took to promote talk and reflection.

- ***The students were aware of being audio-recorded:*** A particular difficulty I encountered was that the students were aware that the activity was being audio-recorded. As a result, the students who usually participated eagerly were somewhat tongue-tied, even though I kept reminding them that only I would have access to the recording. Maybe I should not have referred to audio-recording during the activity.
- ***I complicated the investigation carried out:*** Although the students were able to conclude that the house with a higher ceiling took longer to heat up, there actually was no need to record the temperatures of both houses at regular intervals to arrive at this conclusion. The students could have simply waited until both houses reached a certain temperature and then discussed and explained why they thought that one house took longer than the other to warm up. The way the worksheet (Appendix 3) was designed must have led the students to think that they needed to take multiple recordings.
- ***I could have posed my questions better to promote better scaffolding:*** During this activity, I noted that the students needed scaffolding. Thus, they were asked both closed-ended questions as well as follow-up questions built on their responses. The use of follow-up questions did not, however, enable the students to arrive to the desired conceptual understanding that: *the bigger house needs more time for the temperature to increase by convection currents compared with the smaller house*. Moreover, asking whether the students could give a different explanation to why House B needed more time to get so hot, could have led the students to assume that I implied that Yuri was wrong in stating that since '*House B was bigger, it needed more time to get so hot'*. Stating that a bigger house needs 'more time to get so hot' was actually a valid explanation. Since I was expecting the students to provide an explanation in terms of "convection currents" and "hot air rises", I could have posed a different question, possibly: "*Yes the bigger house needs more time for the temperature to increase compared with the smaller house, but can you explain it in terms of heat transfers?*" I could have also simply asked the student to elaborate. I also feel that I should have made it clear to the students

that they had to think in terms of heat transfers as this could have possibly helped them make connections to what was previously taught.

- ***I may have been too strict in expecting talk to be only in English:*** Since formal and informal assessments are carried out in English, I wanted the students to express themselves in English. possibly, since the proficiency in the English language among the students varied, they felt uncomfortable speaking English, especially when they were being audio-recorded. Despite this, I do not think that asking them to speak English, and being audio-recorded, were the only reasons why connections to scientific knowledge were not made.
- ***I did not provide enough language scaffolding:*** It was my intention to promote the use of technical language in Physics. I mainly did this at the end of the activity during the plenary. I feel that I did not provide enough discourse both to promote reflection as well as to show the students how to refer to heat losses in Physics. I realised that I needed to engage in more scientific exchanges with the students to provide examples and opportunities for them to use technical terms in Physics and make them their own.

These reflections gave rise to the following questions: Should inquiry-based activities be that structured? Should the teaching approach be different? What role should the teacher play in an inquiry-based setting? Should I have discussed more real-life examples before expecting the students to carry out this activity, apply the content learnt to a context and draw conclusions on their own?

Reflecting on the first inquiry-based activity, I realised that teaching the students the scientific concepts in a transmission-based pedagogy, might only result in the students being able to memorise the definitions of these scientific concepts as they might not be able 'to apply the concepts to solve subject-domain problems' (Karpov, 2018, p.104) and incorporate them into their mental scientific 'schema'. I realised that if such activities are to be of most benefit for the students' learning, the students need to be shown how to speak and work together (Mercer, 2008). Thus, I decided that a structured inquiry would be more appropriate as 'important aspects of a task or concept are highlighted' (Hushman and Marley, 2015, p.372). Furthermore, structured inquiry-based strategies 'allow teachers to customize and scaffold learning experiences' (Webb, 2009, p.27). This way of scaffolding the students at first, will guide the students on how questions should be asked and on how answers should be given, i.e. students learn how to justify their explanation. This reflection process made me aware how this research was taking shape while it was being performed. I also became aware of the importance of carefully collecting data and analysing it in a way that enhanced my understanding. This approach, in turn enabled me to plan the next activity better, as well as to reflect on other ways to better analyse the data with respect to my research question.

Collating my reflections and evaluation using Kolb's cycle, Table 4.2 below presents a summary of my experience before the first activity was carried out, my reflection on the outcomes of the IBL activity, the hypotheses that emerged from the analysis, and my plan for the second activity in this cycle.

Table 4.2: *Research design following Kolb's cycle of reflection – Cycle 1 Activity 1*

Stage 1: Experience	Having been a teacher of Mathematics and Physics for twelve years at the time I started this research, I have met many students who experienced difficulties in understanding basic concepts in Physics, struggled to express their ideas and to find the right words to explain their reasoning in English.
Stage 2: Reflections	Reflecting on the first inquiry-based activity provided insights into whether a semi-guided IBL activity enables the students to make connections to what they were previously taught and the amount of guidance they needed to complete such a task and to reach the intended learning outcome. The activity did not promote the talk and reflection which I have aimed for, due to various reasons: investigation expected students to make design decision they are not used to; lack of appropriate scaffolding by me which did not promote adequate discussion and reflection; the students were reluctant to speak in English.
Stage 3: Generalisations/ Hypotheses	Within a setting where students are not used to learn through inquiry and are mainly considered as low achievers, a more structured inquiry would work better. I also need to invest more in scaffolding learning through closed and open-ended questions to enhance the students' ability to propose things, express themselves, see patterns, link variables, explain clearly and suggest conclusions using scientific terminology.
Stage 4: Plan	Two more inquiry-based learning activities will be planned, focusing on the level of support the students need to discuss and reflect on the activities they are involved in and to learn how to express themselves better when explaining the physics involved in their investigations.

Based on the outcomes of my analysis, the following decisions were made with respect to planning the second inquiry-based activity:

- ***The activity required careful structuring***: I need to take into consideration where and why the previous inquiry-based learning activity had failed. One of the changes I made was to discuss more examples before the activity was carried out, that is, invest more in having a more effective engagement phase. I also made sure that the investigation was simple and straightforward.

- ***More attention given to student talk:*** I needed to ensure that there was more student talk during the activity. I intended to achieve this by investing in more and better-quality scaffolding. I planned to achieve this through the use of more questioning, moving from simple reflections to more complex ones to promote discussion and eventually learning.

Evaluating and reflecting on the outcome of each IBL activity through listening to the audio-recordings was invaluable. The reflections and evaluations of this activity fed into the methodology for the second and third activities of this cycle. With the above research design in mind, the second IBL activity of this cycle was planned.

4.4 Activity Two

Based on my reflections on the first activity, I planned this activity as a structured inquiry activity. I based the activity on the topic of “Density”. This activity was carried out over one double lesson. Once again, in this activity, the characteristics of IBL that I tried to implement were based on the 5 E’s model of: 1) engagement (students engage in planning how to carry out the investigation, making sense of their observations/data collected, ask questions seeking clarifications); 2) exploration (plan and carry out the investigation), 3) explanation (students attempt to explain their observation); 4) elaboration (students elaborate on each other’s contributions to draw conclusions about the context they are engaging with); and 5) evaluation.

- ***Engagement:*** In the beginning of the activity, the students were given 10ml of five different liquids: maple syrup; water; alcohol; oil; and concentrated liquid soap; all in identical labeled bottles. The students were invited to first predict which liquids would settle (sink) (underneath water) and which would float (above water). They had to answer the first 3 questions in the worksheet which can be found in Appendix 5. The questions were specifically designed to serve as scaffolding, as the students had to put forward their predication on the context they were presented with (predicting which liquid would float or sink in water).

- ***Exploration:*** The students then had to carry out an investigation where they placed the different liquids in water, observe what happens (observe which ones floated and which ones sank), collect data, compare the results with their predictions and explain the difference (if any). The students were not told in which order to pour the liquids, except that water ideally should be poured in first. The students were reminded that the density of water was $1g/cm^3$. Previously, an experiment to find the density of water had been carried out. The students were divided into four groups and each group was given a worksheet (Appendix 5). The questions in the worksheet were purposely designed to guide the students' thinking and thus, serve as scaffolding to support the students' development of conceptual understanding (Smart and Marshall, 2013). Since the students were not yet very familiar with the IBL approach, by providing the questions, the ownership of the activity was not taken away, but the activity was simply 'presented in a less-threatening way' (Ricketts, 2011, p.57).
- ***Explanation:*** The meaning of density had already been tackled with the students in previous lessons. The discussion revolved about how the greater the mass per unit volume results in the object being denser. The experiment to find the density of water had also been carried out. This activity required the students to link the scientific concept of density to their observations about which liquids float on water and which liquids sink. This activity was also oriented towards mastering factual content by applying the content learned to a context.
- ***Elaboration:*** After carrying out the investigation, each group had the opportunity to take the floor to explain the order of how they had poured the liquids. They were also encouraged to draw a diagram on the board and present their conclusions to the rest of the class.
- ***Evaluation:*** The students' answers to the questions set in the worksheet, as well as their presentations enabled me to evaluate how the students understood the concept of density and how much learning took place.

In this inquiry, each group predicted that oil would float, possibly due to exposure to oil floating on water when cooking at home, or oil spilling in the sea. This showed that the students were able to bring knowledge learned from everyday experiences to the classroom. They were not, however, able to provide an explanation for their observation in terms of density but, were able to identify weight as the main causal factor. In fact, the words “density”, “denser” and “less dense” were not used throughout their discussions as the groups used the word “heavier” in their contributions as can be seen in the transcript below:

Table 4.3: *Transcript 1 – Explanation stage – Activity 2*

Participant	Utterance
Yuri	Which were the liquids that floated? We write oil and alcohol.
Matthew	We write maple syrup and soap for the next questions.
Robert and Yuri nodded	
Yuri	We now write that our predictions were right.
Noel	We have to explain why.
Yuri	Heavier liquids sank, not heavy ones floated.
Noel	Only that?
Yuri	I don’t know what else we can right. You?
Robert	We write what you said.

The students rightly concluded from their observations that maple syrup and soap sank, while oil and alcohol floated. The students were encouraged to provide explanations why certain liquids floated and others sank. Most students agreed that the ‘heavier’ liquids sank.

During the elaboration stage, the densities of each liquid were written on the board and each group had to guess/predict/match the density with the respective liquid. Each group wrote the answers on the class board and they explained why they had drawn those conclusions. There were some mistakes, but while the results were being discussed, the group who had placed the values incorrectly, realised their mistake (the liquids which sank should be matched with the value that represented densities greater than that of water). One possibility that led to the students making this mistake could be that they did not recall that objects with a density less than that of water float, while those with a density greater than that of water sink.

The students’ contributions to the discussion throughout this activity increased when compared with their contributions during the first activity of this cycle. In fact, the students participating in this study made 20 contributions (Table 4.4), more than double those during Activity One.

Table 4.4: *Frequencies of categories – Activity 2*

Category	Frequency of significant students' contributions
Asked/proposed questions	4
The type of question they posed (What? How? Why?)	0
Explained things	1
Made critical statements	0
Made connections between previously acquired knowledge and their observations	5
Expressed patterns	8
Suggested conclusions	2
Made use of scientific terms/language correctly	0
Total	**20**

I noted that the questions in the worksheet promoted talk amongst all the groups, even if none of the groups provided an explanation for their prediction. I made sure to encourage the students to discuss their predictions and to write their explanations.

Their discourse mainly focused on pointing out whether the liquids would float or sink, and then stating that their predictions were correct, without providing any explanations. One student tried to provide an explanation. However, since none of the group members suggested an explanation, he struggled to find the right words to express himself. The group just wrote his statement that "*Heavier liquids sank, not heavy ones floated"*. Moreover, when they were asked to match the densities written on the board to the liquids used throughout the activity, the students did not use the term density, but only mentioned "*maple syrup was the heavier one, so must have the largest density*" as can be seen from the transcript below.

Table 4.5: *Transcript 2 – Explanation stage – Activity 2*

Participant	Utterance
Matthew	Letter A is the density of water as it is 1.
Robert	I agree.
Yuri	Letter C is the largest number. It must be of maple syrup.
Robert	Why?
Yuri	Maple syrup was the heavier one, so must have the largest number.
Robert	So, Letter B is of alcohol as it is the smallest number and alcohol was to the top.
Noel	Yes, yes.
Matthew	The other one less than one is of oil, so letter E is of oil and letter D is larger than one, so it has to be of the concentrated soap.
Yuri	Ok.

In order to promote some reflection on the physical concept under study, I tried to initiate a discussion. My intention was also to obtain some insights about whether the students were actually aware of the physics concept of density in contrast to weight (liquid being heavy) and how density determines whether the liquid would float or sink on water. The discussion that took place during the plenary section, was teacher-led.

Table 4.6: *Coding of contributions at the plenary stage – Activity 2*

Participant	Utterance	Code assigned
Tchr	We have all observed that maple syrup was at the bottom. Which one of these (**referring to the different density values written on the board**) do you think is its density value?	-------------------------------------
Robert	C	Made connections (could also be a guess)
Tchr	Why did you choose letter C? Can you explain your reasoning?	-------------------------------------
Noel	Because it is the largest number.	Explained things as the student attempted to explain why he chose letter C, which had the highest density, to represent maple syrup.
Tchr	I can see that as well. We are investigating why certain liquids sink and others float on water, so try to explain it using those terms?	-------------------------------------
Robert	Maple liquid went to the bottom. Letter C is the largest number, so we think that maple has the largest density, greater than that of water.	Made connections and expressed patterns + Suggested conclusions
Tchr	A clear explanation.	-------------------------------------

Looking at part of the exchange during the plenary of the activity (presented in Table 4.6), it can be noted that the questions I posed aimed to guide the students' thinking and to invite explanations. My interventions enabled students' contributions. Some of the students actually managed to make some connections to what was previously taught in class; that the liquids that sank had a density greater than that of water. In fact, Robert pointed out that letter C had the largest number and maple syrup was the densest liquid since it '*went to the bottom*'. This enabled the students who did not match the density with the correct liquid to make connections to what was previously taught about density. Although the question-answer sequence enabled Robert to provide a good explanation for their conclusion, it has to be pointed out that my role as a challenger did not provide enough opportunity for deeper understanding to take place (Lombard and

Schneider, 2013), because the concept of density being the mass of an object per unit volume was not grasped. This can be noted from his explanation: '*Maple liquid went to the bottom. Letter C is the largest number, so we think that maple syrup has the largest density*'. Though this indicates that Robert was able to demonstrate his understanding that objects with a density greater than that of water sink, it cannot be said that the elaboration characteristic of IBL was reached. This characteristic would have been reached if Robert had stated that the ratio of mass per unit volume of maple syrup is large, therefore its density value should be large, thus, it must be letter C since letter C represents the largest ratio of mass per unit volume. Reflecting on this activity made me realise that towards the end of the activity, the students were able to use the language of physics up to a certain extent: '*Maple liquid went to the bottom. Letter C is the largest number, so we think that maple syrup has the largest density*, *greater than that of water*'. The students concluded that objects with a density greater than that of water sank while others floated. However, they were unable to explain it effectively using scientific terminology. Despite the students were unable to elaborate well on their observations and did not manage to explain the context they were engaging with, using scientific terminology effectively, they still managed to understand that density determined whether a liquid floated or sank.

The second activity thus led to the following conclusions:

- ***Presenting a simpler IBL activity engaged the students more:*** This IBL activity was more straightforward as all the students needed to investigate whether the liquids floated or sank in water. It was less complicated than that in Activity One. This made it easier for the students to understand what they had to do and what they needed to investigate. They were thus more engaged when carrying out the investigation.
- ***The students did not understand well the concept of density*:** The aim of this activity was to implement an IBL activity which enables the students to understand the physical phenomena that determine floating and sinking of liquids. I noticed that while the students were able to determine which liquids floated and which sank, they did not fully grasp the concept of density to explain fully their observations during the investigation. This meant that I did not manage to fully achieve the students' level of understanding that I wanted. This meant that I needed to revisit the concept of density again.

- ***There was more talk during the activity:*** It was observed that the students engaged in more talk during the activity, both during the investigation, as well as during the plenary. While I can consider that there was an improvement in the degree of talk taking place, there was still limited student talk as well as limited reflection. This was demonstrated in the students talking mainly about their predictions of what they expected to happen and what they observed, but not on proposing explanations for their observations. The talk taking place, thus did not demonstrate deep reflection and social construction of knowledge.
- ***The students struggled with using scientific terminology***: The students struggled to find the right words to express themselves when providing explanations for their observations. In fact, during this activity, the students failed to refer to the concept of density, but rather to the numerical value. They also tended to use 'heavier' interchangeably with 'denser'. My interventions, which aimed at guiding the students' thinking and inviting explanation did result in some improvement but were not enough to get the students to use scientific terminology learnt in previous lessons.

When I reflected on this activity, I realised that I wanted my classroom to function as a community of learners, functioning within a Vygotskyan social constructivist framework. Ragoff, Matusov and White (2000, p.381) explain this as a process of transformation of participation where the students take an active role in learning while adults are often responsible for guiding the process. However, the social interactions among my students, though improved, were still limited and thus, did not enable my students to borrow from their more knowledgeable peers the knowledge or skills 'to perform tasks they would not be able to complete on their own' (Eun, 2019, p.21). Furthermore, the amount of scaffolding I provided did not provide the students with enough support to sufficiently grasp the concept of density and its implications for floating and sinking. I could have given the students more time to experience more the concept of density to understand it better. The fact that the students' used 'heavier' and 'denser' interchangeably can be interpreted as either the students have only a partly-developed 'concept' of density, or it might simply reflect imperfect grasp, as yet, of the scientific language. This is another instance which shows that it is critical for students to draw on their non-technical resources as part of the process of coming to understand the scientific concepts which they encounter in their Physics lessons. As a result, I planned to carry out a follow-up lesson on the concept of density, so the students would be provided with more opportunities to experience more the concept and I would ask them questions to help them reflect on their observations and put forward possible explanations.

Table 4.7: *Research design following Kolb's cycle of reflection – Cycle 1 Activity 2*

Stage 1: Experience	From the second IBL activity I noticed that the students were slowly engaging in more discourse. However, they were mainly able to make observations of whether liquids floated or sank and struggled to provide explanations why. They were also unable to use scientific terminology – density- well in their responses.
Stage 2: Reflections	The second IBL activity shows that while the students were becoming more accustomed to IBL, they still needed to learn how to reflect on their observations and put forward possible explanations. I also noticed that they needed to experience more the concept of density to understand it better. They also needed more practice using scientific terminology.
Stage 3: Generalisations/ Hypotheses	The more students experience IBL activities, the more they learn to talk and engage in social construction of knowledge. They will learn physics concepts better as well as learn how to express themselves in the correct scientific way.
Stage 4: Plan	The next inquiry-based learning activity is again on density, focusing on both understanding the concept as well as on how to use technical terms appropriately.

A structured follow-up lesson was planned as the third activity during this cycle of this research. The third activity was therefore related to the topic of "Density" and is described in the section below.

4.5 Activity Three – Follow-up Activity

The third IBL activity focused again on understanding the concept of density. This activity started with a whole class discussion, which was followed by an investigation carried out in groups and a further whole class plenary discussion. The aim of this activity was to get the students to think on the meaning of density, the relation between mass and volume and how it determines whether a liquid sinks or floats on water. The 5E model stages included in the activity were the following:

- ***Engagement:*** The introduction involved a discussion, which focused on the findings of the previous IBL activity, mainly on the conclusion that liquids with a density less than that of water float on water, while those with a density higher than that of water, sink. During this part, I highlighted that in the previous activity they had to provide an explanation to their hypothesis in terms of the densities of the liquids, and that this was different to what they had proposed. I explained that this IBL would help us understand and explain what caused the observations obtained in the previous session.

- ***Exploration:*** Following the initial discussion, the students were then asked to work in groups and each group was given four small 20ml plastic bottles. Each of the bottles contained 20ml of the different liquids which were used in the previous activity: maple syrup, oil, alcohol and concentrated liquid soap. I emphasized that each bottle contained 20ml of liquid. The students were also given an empty bottle. This would have enabled them to calculate the exact density of the liquids using the formula "density = mass/volume" of each liquid. They could do this by first finding the mass of each liquid using an electronic balance and subtracting the mass of the empty bottle from the mass of any bottle containing liquid and then calculating the density of each liquid (even so, the mass of the plastic bottle was much less than that of the liquid and would have not made any significant difference to the density calculated). The reason why I ensured that each bottle contained the same amount of liquid was to make the calculation of density easier. It was also intended to enable the students to realise that the density of an object does not depend on whether an object is heavy or not and neither on its size, but that the density of any object depends on the combination of these two factors: mass per unit volume of the object. The students were then asked to first predict what would happen to each bottle if they had to put them in a bowl of water.
- ***Explanation:*** The worksheet that guided the students during the investigation included questions which invited them to reflect on their observations and to provide explanations based on their observations. They were also told that they would be discussing their observations and ideas as a class later-on during the plenary.
- ***Elaboration:*** The plenary at the end of the activity aimed at promoting better understanding of density of liquids by guiding the students to understand that the same volume of the liquids had different mass, and it was the combination of mass and volume together, not only one of the factors (mass as they had originally thought) determined whether the

bottles floated or sank.

- ***Evaluation:*** The concept of density is very difficult for secondary students to understand clearly. This final stage included my reflection on how much the students had demonstrated their conceptualization of the two factors of mass and volume when talking about density.

My analysis of the discourse taking place focused on the discussion that took place at the plenary section of this activity. The frequency of each category is presented in Table 4.8. It can be noted that students' contributions were less than in Activity Two but more than in Activity One. There were mainly more attempts to explain the physical phenomenon of density observed and more attempts at using technical language. None the less, I did not feel that there was acceptable increase in the quality of the students' contributions as well as in their frequency

Then, they had to take note of their observations and compare their results with their predictions by carrying out the investigation. They were also told that they would be discussing their observations and ideas as a class.

Table 4.8: *Frequencies of categories – Activity 3*

Category	Frequency of significant students' contributions
Asked/proposed questions	1
The type of question they posed (What? How? Why?)	0
Explained things	4
Made critical statements	1
Made connections between previously acquired knowledge and their observations	1
Expressed patterns	1
Suggested conclusions	0
Made use of scientific terms/language correctly	3
Total	**11**

Table 4.9 presents further insight into the students' contributions. Looking at the excerpt presented in Table 4.9 overleaf, it can be noted that this follow-up activity provided the students with an opportunity to explain the concept they were engaging with and to also make connections, even though some of their explanations and the connections they made were not scientifically correct, this mainly as the weight was still considered as the determining factor.

My interventions varied from a simple question requesting the students to report directly what they had observed, to inviting explanations based on their observations and to explain their observations using both the knowledge learnt in previous lessons as well as the scientific language learnt. My intention was to try and scaffold the students' learning by guiding their development of understanding, through the use of the question-and-answer sequence, which was not intended to just test the students' knowledge. However, my questions tended to be too guided, with the students mainly aiming more at identifying the pre-determined correct answer and less in discussing the outcomes of the investigation as I wanted them to do.

On the other hand, it could be noted that during this activity, the students improved in their ability to use scientific language correctly. The transcript of the discussion that took place during the plenary stage of this lesson can be found in Appendix 7.

Table 4.9: *Coding of contributions at the plenary stage – Activity 3*

Participant	Utterance	Code assigned
Tchr	What did you observe?	-------------------------------------
Robert	The one containing oil floated.	-------------------------------------
Tchr	Can you explain why the bottle containing oil floated on water?	-------------------------------------
Noel	Oil always floats.	Expressed patterns
Tchr	Oil always floats on water. Can you explain this in terms of density?	-------------------------------------
Noel	mmmm the density of oil is less than that of water. Yes?	Explained things + Asked questions
Yuri	Aha, yes, the density of oil is less than that of water.	-------------------------------------
Tchr	All the bottles contained the same volume. Can someone tell me what other variable affects the density of an object?	-------------------------------------
Robert	The weight.	Explained things
Tchr	What do you mean by weight?	-------------------------------------
Robert	How heavy it is.	Explained things
Tchr	Ok. What is the formula to calculate the density?	-------------------------------------
Robert	Mass over volume	--------------------------------------
Robert	Ahh so mass not weight uff.	--------------------------------------
Tchr	Good. So, can someone tell me what was different between these liquids since some sank and some floated?	-------------------------------------
Matthew	Their mass.	Made connections
Tchr	If a new student joins our class today and wants to know what density is and why some objects floated, and others sank, how would you explain to him what you mean by 'mass per unit volume'?	-------------------------------------

Yuri	I would tell him to put 1ml of the liquid in a measuring cylinder and to find the mass of it. Then, to do the same with the others. He will see that the masses are different, so mass per 1 volume is different, so density of them is different. Those with a density bigger than water will sink, the others will float.	Explained things + Made critical statements + scientific language
Tchr	Great. You would surely be of great help to a new classmate.	-------------------------------------

One of the questions asked was open-ended: '*If a new student joins our class today and wants to know what density is and why some objects floated, and others sank, how would you explain to him what you mean by 'mass per unit volume'?*'. This aimed at encouraging the students to reflect on what they had observed and to also reflect on the concept they were engaging with. I tried to pose questions aimed at helping the students reach the elaboration stage of IBL. This was only partially successful, mainly through the explanations given by Yuri about why certain liquids float on water and others sink. His explanation was more elaborate and accurate than the one Robert provided during the previous activity (Activity 2) as can be seen from their contributions presented below. Yuri's response to this open-ended question shows how the question I posed positioned him as an expert (in Vygotskian terms, a more knowledgeable peer working within other students' ZDP), and thus in inhabiting this role, he became more 'conscious and reflective' (Eun, 2019, p.23).

Robert: Maple liquid went to the bottom. Letter C is the largest number, so we think that maple has the largest density, greater than that of water. *(Activity 2)*

Yuri: I would tell him to put 1ml of the liquid in a measuring cylinder and to find the mass of it. Then, to do the same with the others. He will see that the masses are different, so mass per 1 volume is different, so density of them is different. Those with a density bigger than water will sink, the others will float. *(Activity 3)*

The students' explanations demonstrate that the follow up activity provided them with an opportunity both to improve their understanding of the concept of density as well as of their ability to express themselves. I had made an improvement in supporting the students in their capability to explain themselves. They made connections, provided a longer chain of reasoning as well as suggested conclusions. They also made more correct use of some scientific language. Therefore, the questions posed during the follow-up activity turned out to be a 'tool for students' thinking promotion' (Larrain et al., 2014, p.12).

Reflecting and evaluating this activity revealed that dedicating more than one activity to the same concept can be very powerful, as students are given the opportunity to describe and explain events differently, resulting in more insightful learning 'as a consequence of more sophisticated understanding' (Hodson, 2014, p.2541). The explanation given by Yuri is a clear example of how repeating activities can be highly effective in prompting more complex and detailed explanations, as Yuri was able to explain, in his own way, that the mass per unit volume of different objects is different, and this results in different densities, which is a valid explanation. Although the student did not mention that the greater the mass per unit volume, the greater the density of that object would be, his structured explanation indicated that providing some form of scaffolding enables the students to make more appropriate explanations and make connections between their observations and the scientific concepts. Hence, this approach provided an opportunity for understanding to take place (Lombard and Schneider, 2013), as the questions asked stimulated further reasoning about the relationship between mass per unit volume among the students both during the activity and during the plenary part of the lesson (Huerta and Jackson, 2010).

In gathering together these observations, the following conclusions about Activity 3 were drawn:

- ***Tackling a Physical concept more than once resulted in deeper learning:*** Activity 3 showed the value to taking time to tackle physics phenomena as it promotes more and deeper understanding. This was demonstrated in how the students started relating to density as a combination of mass and volume, an aspect which was not mentioned directly in Activity 2.
- ***Being more careful to my scaffolding promoted more reflection:*** I realised how the quality of my questions and contributions to the discussion elicited different types of responses from the students. I could see how I could venture from closed to open questions, eliciting more discussions and less of

a search for the pre-determined correct answer. I noticed that I have improved with respect to how I engage in discourse with my students, providing scaffolding which promotes reflection on observations made. I am, none the less, aware that I still need to improve in how to provide scaffolding, an aspect which I intend to continue to work on.

- ***There was some improvement in the correct use of technical language:*** I noticed that there were more instances where the students used the correct physics terminology when explaining what they had learnt. I was pleased with this evident improvement, even if it was not noted among all the students.
- ***While improvements were observed, students' discourse was still limited:*** While there was an improvement in both understanding and in the use of technical language, this was still limited and not observed in all the students participating in the study. I was still sticking to the strict use of the English language during the Physics lesson. The language barrier may be one reason for which the students did not engage in as much discussion as I would have liked. While the students could understand the English language, they overall struggled to express themselves in English. The most appropriate explanation was put forward by Yuri (the student who preferred to express himself in English). This shed light that the strict use of the English language was possibly hindering the first language Maltese speakers from communicating appropriate explanations, especially since they were able to provide an explanation when discussing among themselves in Maltese. This activity made me ponder whether the strict use of the English language may be interfering with the students' learning process during these activities. I wondered whether allowing the students to express themselves in their preferred language would elicit more talk during the next inquiries.

Considering these aspects, I organized my reflections using Kolb's cycle as shown overleaf:

Table 4.10: *Research design following Kolb's cycle of reflection – Cycle 1 Activity 3*

Stage 1: Experience	From the third IBL activity, I noticed that the students had achieved greater understanding of the concept of density. I also noticed that they were also putting forward more potential explanations for the observations made. There was also an improvement in their use of correction scientific terminology. However, overall, there was still a lack of overall class talk and social construction of knowledge. I noticed that most contributions were being made by the student who preferred to talk in English.
Stage 2: Reflections	While I noticed that as I was improving my skills in delivering IBL activities, the overall improvement in learning was limited. The students did demonstrate better learning and more attempts to present explanations, using correct technical terminology. However, there was still insufficient talk among students. Since the activity was conducted strictly in English, I concluded that there could be a language barrier for some students who were not that proficient in the language. The language barrier could be limiting the students from engaging in exploratory discussion, limiting the amount of social construction of knowledge which was taking place during the inquiry activity.
Stage 3: Generalisations/ Hypotheses	My hypothesis is that now that I have gained experience in implementing IBL activities, that there could be more opportunities for the social construction of knowledge, if students are allowed, to discuss in their preferred language.
Stage 4: Plan	The next inquiry-based activities in Cycle two should focus on language used by students to see whether a more open approach to language use (where students can choose English or Maltese as they prefer), can promote better social construction of knowledge as well as better understanding.

4.6 Summary And Findings Drawn From Cycle One

This cycle started with me, as a teacher, trying out a guided inquiry leading to understanding of a specific physics concept. In this activity, the students were expected to make connections between the heat losses from two different model houses in an investigation. While the students managed to conduct the investigation, and that the house with a higher ceiling took longer to warm up, they struggled to explain their observations and make connections using physics concepts learnt in previous lessons. There was also very limited discussion taking place. My evaluation and reflection on this activity was that the students needed to become accustomed to this pedagogy and be scaffolded better. A more structured second IBL activity was planned.

The second activity focused on promoting more talk among the students, which fostered explanations about what was going on. This resulted in more instances of construction of knowledge, even if still in limited amount. In this activity, the students also made use of some scientific terminology cogently in their concluding comments. Though the students made some connections to previously learnt physics concepts, they still did not demonstrate good understanding of the concept of density. As a result, a structured follow-up activity was planned.

In the third activity, I focused on posing questions aimed specifically to scaffold learning. The questions I asked after the investigation was carried out managed to guide the students' development of understanding, stimulate their thinking and encourage reflections on their observations. This activity saw a shift, even if a limited one, in some students' explanations for their observation. In these few instances, they provided a longer chain of reasoning, as well as made connections between their observations and physics concepts previously learnt to draw the right conclusions, using the correct scientific terminology. This impact, however, was observed only among few students.

As a result of the insights obtained from this cycle, I have learnt that structured and guided approaches are more effective in bringing about learning when compared with an approach that offers minimal guidance. This is in accordance with how Hmelo-Silver et al. (2007) and Kirschner et al. (2006) described the effects of structured and guided approaches to learning. Vygotsky's insights about the relationship of thought to word, that 'thought is not expressed but completed in the word' (Vygotsky, 1987, p.250), made me ponder on the role language plays in enabling students to develop their ideas in and through language. The language the students use to each other and to me as their teacher, enables learning and enables them to verbalise their scientific knowledge. Thus, the evaluations and reflections of this cycle also made me ponder on whether the strict use of the English language was potentially 'one of the principal obstacles' (Evnitskaya, 2012, p.68), which hindered the co-construction of knowledge between the teacher and the first language Maltese speakers as well as among these students (Borg, 2010). With this hypothesis in mind, another set of IBL activities with a focus on language use was planned for Cycle Two. The methodological approach and its analysis is presented in the next chapter.

Methodology – Cycle Two

5.0 Introduction to the chapter

This chapter presents the research design adopted during the second cycle of this study, which was composed of three inquiry-based activities. The first two activities involved going through the Kolb cycle: the experience, the reflections, the hypotheses generated from the reflections and planning of the following activity. The third activity also consisted of a Kolb's cycle. However, since it was the last IBL activity implemented, its final stage did not focus on planning but on identifying what needed to be further clarified on the conclusions drawn, in the interviews, which were carried out at the end of the activities. My reflections on the three activities in Cycle One led me to acknowledge that the students, while demonstrating some more understanding, still struggled to explain the concepts they were engaging with. On the other hand, I also noticed that the students were slowly engaging in more discourse during the second activity. However, they were mainly able to make observations of whether liquids floated or sank and struggled to provide explanations why. Moreover, during the third activity, which was a follow-up activity, I noticed that as I was improving my skills in delivering IBL activities, the overall improvement in learning was limited. The students did demonstrate better learning and more attempts to present explanations, using correct technical terminology. However, there was still insufficient talk among the students. Thus, the reflection and evaluation processes of the first cycle of this research provided insights on the possibility that the strict use of the English language was hindering the students whose proficiency in English varied, from expressing themselves clearly. With Vygotsky's insights about the relationship of thought to word in mind, Cycle Two focused on the relationship between the language used in the classroom and the students' ability to talk science within an inquiry-based setting. The following research question was set for Cycle Two:

How does a bilingual approach impede or support students in constructing knowledge of physics concepts in a linguistically-mixed group?

During Cycle Two, the students were not expected to speak solely in the English language when discussing in groups but were instead encouraged to express themselves freely in any of the two languages (English or Maltese) or a mixture of both (code-switching), whichever they felt more comfortable with when expressing themselves. This study thus also focused on the important role language plays in enabling the students to develop their ideas in and through language, at the point of utterance, as the language the students used to each other enabled them to verbalise their scientific knowledge and understanding, which in turn, enabled me to evidence their learning. For this part of my study, two structured and one guided/open inquiry-based activities were planned and implemented. I opted for structured inquiries followed by an open/guided one not only as a result of the indications, which the reflections and the evaluations of Cycle One of this study had provided me with, but also because of personal beliefs. I believed that students needed to be doing science 'with judicious teacher assistance and support' (Hodson, 2014, p.2547) until they become more skilled and more confident to engage in inquiries, and where the role of the teacher is less active (Burgh and Nichols, 2012) since unguided inquiry gives students more independence. The table below presents a brief idea of these activities.

Table 5.0: Activities implemented in Cycle Two

Activity 1	A structured-inquiry activity on the topic of Energy and Work Done	One double lesson (2 lessons of 40 minutes each)
Activity 2	A structured-inquiry activity on the topic of Light	One double lesson (2 lessons of 40 minutes each)
Activity 3	A guided/open-inquiry activity on the topic of Forces	Two double lessons (4 lessons of 40 minutes each)

The next section discusses the data collection process adopted for this part of this study.

5.1 Data Collection

Data collection for Cycle Two was carried out over a period of two scholastic years, September 2017 – May 2019. Table 5.1 below presents the time-frame during which the data for Cycle Two was collected.

Table 5.1: Time-frame for data-collection

Scholastic Year	**Date**	**Data-Collection Instrument**
2017-2018	End of November 2017	Activity 1: Burning off the calories of a Mars bar
	Mid-January 2018	Activity 2: Exploring Light through Prisms
	Mid-May 2018	Activity 3: Egg drop – Land it safely
2018-2019	Mid-January 2019	Piloting of semi-structured interviews
	February-end of March 2019	Semi-structured interviews

The data was collected by me as both the teacher and the researcher. For analytical purposes, I refer to myself as the “teacher” or as “I” throughout this study. The empirical data examined covered three IBL activities. Firstly, I wrote field notes explaining what the students’ contributions were (to report observation, to ask a question, to reply to a question, to explain their observations). Then, the interactions of each activity were analysed separately based on the sets of main codes and sub-codes that emerged: science codes and language codes. This aimed at obtaining insights on whether these activities promoted better understanding of concepts among my students and at understanding the role of language during the discussions, as well as the role of the teacher in an IBL setting. Taken together, these three activities provided a comprehensive and deeper picture of whether using more discussions and promoting more talk within an IBL setting resulted in better understanding of physical concepts and improved the students’ ability to talk science when expressing their scientific knowledge and understanding. The whole data corpus on which the analyses were carried out included both conversational data and complementary data sources, such as field notes.

The participants were again, me as the teacher of Physics, my same students of last year who were now in their second year of studying Physics and another first language Maltese speaker who was proficient in both English and Maltese, who joined my class during his second year of studying Physics. Keith was confident and able to discuss and share ideas during the Physics lessons. He was also friendly, easy-going and got on well with his peers. His proficiency in both Maltese and English and his personality did not affect the dynamics of the group. In fact, he appeared to be more knowledgeable than Robert and Matthias, and his ability to use different language repertoires whilst moving fluidly between the two languages, enhanced the way my classroom functioned as a community of learners and functioned within a Vygotskyan social constructivist framework.

The data sources for Cycle Two of this research once again included:

- **Field notes from lessons** (focusing mainly on the teacher’s interventions to elicit what the students think, to encourage elaboration on their previous answers and to guide and help students construct their own meaning (Chin, 2006);

- **Audio-taped class conversations** of class and group discussions involving the same students participating in this study; and
- **Transcripts of class conversations** which included the introduction of each activity, any whole class discussions that took place as well as the conversations among target group during group work, which were then transcribed word for word.

The analysis of the data aimed at identifying whether students benefitted from such activities by looking for valid explanations, ideally, accompanied by the good use of specialized technical language. For example, it is not enough for students to say that oil floats on water because its density is less than that of water, they need to demonstrate that they know why and can explain the reasoning for such assertions.

The next section provides the reasons why I, as the researcher and the teacher felt that the categories adopted to analyse the students' discourse during Cycle One needed to be nuanced.

5.2 Description of codes

Since this study involves action research, where as a practitioner I wanted to improve the quality of the teaching and learning of my students (Tillotson, 2000), the sequence of analysis could not be predetermined, but emerged throughout the analysis and data collection processes. In fact, the analysis of Cycle Two was at first planned to be organized around the same content analysis adopted during the first cycle. The plan was to then tabulate the categories mentioned in section 3.9 (Table 3.0) to determine the dominant ones (the number of times made) across the data, first in each activity separately and then by comparing them, to note any differences and/or similarities. In other words, to note whether there had been a shift among the dominant categories between the three IBL activities carried out during Cycle Two. However, when the first activity of Cycle Two was coded using these categories, only a rough picture about the way students explained things was obtained. As a result, I referred to the transcript and included side notes, explaining the students' contributions. I then coded their contributions, which led to the emergence of some codes. On revisiting the coding, I realised some codes overlapped and others were ambiguous, leading to a further refinement of the codes.

Since the aim of this study was to find out whether adopting an inquiry-based learning approach promotes better understanding of concepts in Physics and greater proficiency in talking about scientific ideas, it was deemed fit to code the sentences to provide information on how students reasoned, used knowledge to explain and their attempts to elaborate on previously shared ideas in order to make sense of the concept and the context they were engaging with, as well as for the language used throughout the discussions. As complex as the data analysis process may be, efficient attempts to identify emerging codes from the corpus of data collected were made.

5.2.1 Description of science codes

Since the first coding process led to too many codes, some of which overlapped and some were even ambiguous, I decided to look at the codes Hogan, Nastasi and Pressley (1999) used in their study, since their research was similar to the one underpinning this thesis. Their research explored whether teacher-led discussions or student-led discussions in two science classrooms yielded higher levels of reasoning and higher quality of explanations. As a result, the main science codes for the inquiry-based learning in science used to analyse the data generated from this study were adapted from Hogan, Nastasi and Pressley (1999). Adopting and adapting their codes was useful to my study in generating knowledge about classroom practices where knowledge is constructed through peer and teacher discussions.

The following are the inquiry-based learning in science main codes that were adopted and adapted from Hogan, Nastasi and Pressley (1999) and used to analyse the students' contributions:

1. Observation statement (when the student reports directly what they observe)
2. Replies to questions (when the student answers questions either posed by the teacher or peers)
3. Use knowledge to explain (when the student uses knowledge to explain)

4. Student elaboration (when the student attempts to elaborate on previously shared ideas)
5. Student asking questions (when the student asks the teacher or his peers a question)
6. Student uncertainty statement (when the student expresses uncertainty about a statement or question)
7. Student rebuttal (when the student rebuts the ideas or suggested methods put forward by their peers)
8. Student acknowledgement by affirmation (when the student acknowledges by affirming contributions put forward by peers)
9. Logistical (when the student discusses aspects of the task, for example, what to do and how to carry it out)
10. Off-task (when the student discusses something that has nothing to do with the topic/task)
11. Teacher Input (when the teacher intervenes)

However, when analysing the data guiding Cycle Two of this study, the importance of including other codes arose. Thus, in addition to identifying the main codes, a fine-grained analysis of the contributions both the students and I, as their teacher made during the discussion was carried out. The fine-grained analysis of the contributions led to the emergence of a number of sub-codes. These sub-codes were included where necessary, to analyse the data further. Table 5.2 overleaf presents the final main codes (adapted and adopted from Hogan, Nastasi and Pressley (1999)), and the sub-codes (which emerged). It also provides an example for each main code and sub-code mainly from Activity 2 (Exploring Light through Prisms) carried out during Cycle Two. The number in the bracket denotes the contribution number throughout the discussion.

Table 5.2: Main codes, sub-codes, explanations and examples

Inquiry-based learning in science main codes	Explanation	Sub-codes	Explanation + Example
Code 1: Student Observation Statement (SObS)	This refers to a contribution where the students report directly what they observe.	**SObS-EvdL**	The student reports directly what they observe using everyday language. ***Example:*** *(11 – Noel) And* ***purple.***
		SObS-SL	The student reports directly what they observe using scientific language or words that form part of the Physics repertoire. ***Example:*** *(94 – Robert) The one closer to the* ***light bulb*** *only was seen.*
Code 2: Student Replies to Questions (SRQ)	This refers to a contribution where the students answer questions either posed by the teacher or peers.	**SRQ-ObS**	The student answers a question by reporting directly what they observe. ***Example:*** (9 – Keith) So, we write red, orange, green, blue and pink? *(10 – Robert) I didn't see* ***pink*** *and you forgot to mention* ***yellow****.*
		SRQ-EvdL	The student answers a question using everyday language. ***Example:*** (44 – Robert) How are we going to explain it? *(45 – Keith) We would see a lot of colours, but not* ***bright.***
		SRQ-SL	The student answers a question using scientific language or words that form part of the Physics repertoire. **Example:** *(109 – Keith) A prism refracts white light into colours (those colours) and produces the spectrum of white light.*
Code 3: Student Uses Knowledge to Explain (SUKE)	This refers to a contribution where the students use knowledge to explain.	**SUKE-EvdL**	The student uses everyday language to explain. ***Example:*** *(49 – Keith)* ***Perfect red****,* ***perfect blue*** *and so on. I can't explain it properly. When we switch on the* ***bulb****, I'll show you what I mean.*

		SUKE-SL	The student uses scientific language or words that form part of the Physics repertoire to explain. ***Example:*** *(53 – Keith) The* ***beam of light*** *at the end of it won't be* ***strong****, so I think that we have to write that as we move the* ***spectrum*** *away, the* ***spectrum*** *would be* ***lighter****. If we move it closer, the* ***spectrum*** *would be* ***brighter and sharper****.*
		SUKE-Hyp	The student shares own hypothesis as part of the explanation. ***Example:*** (55 – Noel) What do you think the colour of the beam will be on emerging from the slit? *(56 – Robert) It will be white as the* ***slit*** *won't affect it.*
		SUKE-SM	The student shares a scientific misconception as part of the explanation. ***Example:*** *(24 – Keith) Light reflects the colours through the bubble.*
Code 4: **Student Elaboration (SElb)**	This refers to a contribution where the students attempt to elaborate on previously shared ideas.	**SElb-EvdL**	The student elaborates on previously shared knowledge (either scientific or everyday knowledge) using everyday language. ***Example:*** *(46 – Robert) And if you move it closer, the colours would be* ***bright****.*
		SElb-SL	The student elaborates on previously shared knowledge (either scientific or everyday) using scientific language or words that form part of the Physics repertoire. ***Example:*** *(111 – Robert) …we can add that* ***when white light enters a prism, the beam of light is refracted, and it produces the colours*** *and we write them and then finish off with what Keith said?*
Code 5: **Student Asking Questions**	This refers to when the students ask a	**SAsQ-EvdL**	The student asks a question using everyday language to seek scientific knowledge. ***Example:***

(SAsQ)	question to the teacher or their peers.		*(59 – Robert) Could it be that the **prism** acts like a **bubble**?*
		SAsQ-SL	The student asks a question using scientific language to seek further scientific knowledge. ***Example:*** *(81 – Robert) The **emergent ray** will be the colour of the **filter** used. Does the **filter absorbs** the other colours?*
		SAsQ-Log	The student asks a question requesting a logistical response. ***Example:*** *(21 – Noel) So we write red, orange, yellow, green, blue, indigo and violet or violet and indigo?*
		SAsQ-Clr	The student asks a question seeking clarification about comments made by peers. ***Example:*** (59 – Robert) Could it be that the **prism** acts like a **bubble**? *(60 – Keith) What do you mean?*
Code 6: Student Uncertainty Statement (SUnS)	This refers to when the students express uncertainty to a statement or question.	----------------------	***Example:*** *(37 – Robert) I don't know. I don't think so.*
Code 7: Student Rebuttal (SReb)	This refers to a contribution where the students rebut the ideas or suggested methods put forward by their peers.	**SReb-PEK**	The student rebuts everyday knowledge put forward by peers. ***Example:*** (17 – Noel) More like **violet**. (18 – Robert) They are the same. *(19 – Keith) No, they are called **indigo** and **violet**.*
		SReb-PSK	The student rebuts scientific knowledge put forward by peers. ***Example:*** *(31 – Keith) Light would still be **reflected**, otherwise we won't see the **objects**, but there won't be **colours**.*
		SReb-PM	The student rebuts a suggested method put forward by peers. ***Example:***

			(82 – Keith) We can drop it form a height of **half a metre**. *(83 – Noel) It will still break on an empty* ***tray****. Do you remember that it broke on the bench from a height of* ***30cm****?* This example is from Activity 3 as this code could not be found in Activity 2.
Code 8: Student Acknowledgement by Affirmation (SAck-Aff)	This refers to when the students acknowledge by affirming contributions put forward by peers.		***Example:*** *(13 – Noel) Yes it looked like a* ***rainbow****.*
Code 9: Student Logistical (SLog)	This refers to when the students discuss aspects of the task, for example, what to do and how to carry it out.	---------------------	***Example:*** *(7 – Robert) I think that we have to write down the colours we saw.*
Code 10: Student Off-task (SOff)	This refers to when the students discuss something that has nothing to do with the topic/task.	---------------------	***Example:*** *(93 – Matthew) We bring a boiled egg from home. (giggles)*
Code 11: Teacher Input (TchI)	This refers to when the teacher intervenes.	**TchI-E**	The teacher intervenes to invite explanations or further elaborations. ***Example:*** *(108 – Tch) Can you elaborate a bit more?*
		TchI-S	The teacher intervenes to scaffold the students' thinking.

			Example: *(74 – Tch) So, when an object reflects light, we see the object, if a prism reflects light, what are we supposed (expecting) to see?*
		TchI-R	The teacher replies to students' questions. ***Example:*** (14 – Keith) Can we do another bubble miss please? *(15 – Tch) Yes sure. The solution is here.*

* text in italics denotes example

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote students speaking entirely in Maltese

As mentioned in the introduction of this chapter, the reflection and evaluation processes of the first cycle provided an intuition that asking the students to use the English language when engaging in teacher-led and group discussions was probably hindering the students from expressing themselves clearly, leading to valuable contributions to the discussion to be squandered. Thus, Cycle Two also looks at the relationship between the language used when the students were encouraged to use their preferred language, i.e., English, Maltese or a mixture of both (code-switching) and their ability to talk science. As a result, a set of codes focusing on the language used was needed. The section below explains how the codes to analyse the language used emerged.

5.2.2 Language Codes

The first set of language codes was quite simple and predetermined; English, Maltese, code-switching. The first activity (Burning off the calories of a Mars bar) was coded. Each contribution put forward was assigned one of the codes: English; Maltese; or code-switching. This did not provide enough insights into when and how different language repertoires were used, and thus, it was decided to look at the students' contribution and look at whether when code-switching, the students used English either for specialised technical words, non-technical words related to the activity, mixture of both technical and non-technical words or for words which although cannot be considered as specialised technical terms, are part of the Physics repertoire. Though this gave a better picture, that is, the first language Maltese speakers used the three different language repertoires to different degree depending on their proficiency in the English language, it still felt that such coding was not providing enough insights into when and why these language repertoires were used. At this time, it was assumed that applying the science codes and sub-codes (found in table 5.2) to the three different language repertoires would give a better picture, however, this resulted into too many codes and sub-codes. Since this turned out to be rather complex, a new way of how to look at the data needed to be found. It was decided to go through the whole group discussion of Activity 1 and adopt an interpretive approach. While keeping the main codes (English, Maltese and code-switching), side notes explaining each contribution put forward, for example, 'reasoning', 'recording data', 'explaining data', as described below were added. This enabled the following codes to emerge:

- Code 1: Reasoning and demonstrating scientific understanding
- Code 2: Recording and/or collecting data
- Code 3: Reporting data and/or observation
- Code 4: Explaining data
- Code 5: Investigative design
- Code 6: Questioning
- Code 7: Agreement and/or disagreement with peers' inputs
- Code 8: Expressing certainty or uncertainty about what was being discussed, reported and proposed
- Code 9: Accuracy of measuring, recording data and carrying out calculations
- Code 10: Demonstrating misconceptions or incorrect scientific knowledge
- Code 11: Predicting
- Code 12: Thinking

After validating the above codes with the main supervisor and both co-supervisors, it was concluded that some codes overlapped while others were ambiguous. Thus, a fine-grained analysis was carried out and certain codes were grouped together. As a result, the nuanced codes that emerged were the following:

- Code 1: Reasoning and explaining
- Code 2: Investigative design
- Code 3: Data
- Code 4: Observation
- Code 5: Accuracy
- Code 6: Predicting
- Code 7: Questioning
- Code 8: Demonstrating misconceptions or incorrect scientific knowledge

Table 5.3 overleaf presents these codes, explanations of codes, abbreviations of codes and where necessary, abbreviation of sub-codes. It also provides an example for each main-code and sub-code mainly from Activity 1 (Burning off the calories of a Mars bar). The number in the bracket denotes the contribution number throughout the discussion.

Table 5.3: Language codes, explanations, abbreviations and examples

Codes	Explanation of codes	Abbreviations of codes and sub-codes	Explanation + Example
Code 1 – Reasoning and explaining	Students demonstrate their reasoning without scientific concepts.	R-NoSC	Student demonstrates his reasoning of how to calculate the height of the staircase in his reply to peer's question. ***Example:*** (28 – Matthew) How are we going to calculate the height of the staircase? *(29 – Robert) We measure the height of **1 step** and then **multiply it** by the number of **steps**.*
	Students demonstrate their reasoning with scientific concepts.	R-SC	Student demonstrates his reasoning that a person who weighs more would get more tired when performing the same exercise as a person whose weight is less. ***Example:*** *(75 – Robert) Oh. Yes. True Yuri, I agree. So, Matthew used, **generated more power** because **his work done was the largest** and not because he was the **slowest**.*
Code 2 – Investigative Design	Students suggest ways how to carry out the investigation and/or when carrying out the necessary calculations.	ID	Student shares his idea on how to tackle the uncertainty expressed earlier by his peer about the method adopted by the group. ***Example:*** *(44 – Yuri) Let me go up and give you the measuring tape and we measure the height of all the steps together.*
Code 3 – Data	Students discuss ways on how to record data.	D-RC	Student replies to peer's question about the correct unit to document their measurement. ***Example:*** *(36 – Robert) Yes, **distance** is always measured in **metres**. Just studied the **SI units** and for **distance** and **length** we use **metres** so we have to convert it.*
	Students report directly the data collected.	D-Rep	Student reports the data measured in response to peer's question. ***Example:*** (39 – Noel) In metres? *(40 – Robert) 0.16*
	Students explain data.	D-Exp	Student explains data by explaining peer's observational statement.

			Example: (60 – Noel) We all got different results. *(61 – Yuri) Duhhh. Of course, since our body weight is different.*
Code 4 - Observations	Students report directly their observations.	Obs	Student reports directly their observation. ***Example:*** *(69 – Robert) So the **prism** is producing these **colours**.* This example is from Activity 2 as this code could not be found in Activity 1.
Code 5 - Accuracy	Students emphasize on accuracy in measuring data.	A-MD	Student ensures accuracy which is an important process skill when carrying out an experiment/ investigation. ***Example:*** *(43 – Noel)* I don't think that the **steps** are of the same **height** though.
	Students emphasize on accuracy when reporting data.	A-RD	Student asks a logistical question to ensure correct reporting of data as the SI units for distance, length and height is metres. ***Example:*** (38 – Robert) 1 **step** is **16cm**. *(39 – Noel) In metres?*
	Students emphasize on accuracy when carrying out necessary calculation.	A-C	Student ensures accuracy which is an important process skill when carrying out an experiment/ investigation. ***Example:*** *(53 – Robert) Ok. Do you agree that it is on the **30cm mark**? I can't see properly from up here.* This example is from Activity 3 as this code could not be found in Activity 1.
Code 6 - Predicting	Students share their prediction about the outcome of their investigation.	P	Student predicts the effect on the white beam of light as it leaves the prism when a coloured filter is placed in the path of the white beam before it enters the prism. ***Example:*** *(81 – Robert) The **emergent ray** will be the colour of the **filter** used.*

			This example is from Activity 2 as this code could not be found in Activity 1.
Code 7 - Questioning	Students ask questions to peers and/or the teacher to request logistical information.	Q-L	Student asks a logistical question to the teacher. ***Example:*** *(5 – Noel) So we write rainbow colours?* This example is from Activity 2 as this code could not be found in Activity 1.
	Students ask questions to peers and/or the teacher to request procedural information.	Q-P	Student asks the teacher a question seeking procedural assistance. ***Example:*** *(51 – Robert) How are we going to calculate our power?*
	Students ask questions to peers and/or the teacher to request further clarification.	Q-C	Student asks the teacher a question seeking clarification about the results obtained. ***Example:*** *(70 – Robert) Matthew used more power. Does it mean that the slowest person used more fuel and generated more power Miss?*
Code 8 – Demonstrating misconceptions or incorrect scientific knowledge.	Students share misconceptions or incorrect scientific knowledge when planning the investigation and/or when attempting to make connections between their observation and previously acquired knowledge to draw conclusions.	Msc	Student shares a misconception that they see the colours on the surface of the bubbles because the bubbles reflected the colours of the surroundings when this happens because the bubble refracted the beam of light passing through it. ***Example:*** *(30 – Robert) But do you know why it came out as* ***different colours****? Because they got* ***reflected****. If everything is white, nothing will get* ***reflected****. I think the* ***answer*** *is no.* This example is from Activity 2 as this code could not be found in Activity 1.

* text in italics denotes example

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote students speaking entirely in Maltese

The above codes and sub-codes were first applied to Activity 1 of Cycle Two. Then, code checking for reliability was carried out by the main supervisor as well as both co-supervisors and the codes and sub-codes were applied to the three activities implemented in Cycle Two. Once these three activities were analysed, semi-structured interview questions were planned and piloted, as discussed in the section below.

5.3 Semi-structured interviews

After the three activities implemented during Cycle Two were analysed, semi-structured interviews were planned. The semi-structured interviews were conducted when the students were in their final year of compulsory schooling (Year 11), during the scholastic year 2018-2019. The interviews mainly sought the students' views on the learning of Physics, particularly on the effect of inquiry-based learning activities on their learning in the Physics classroom. This study also aimed at finding out whether affording the students the freedom to use their preferred language repertoire during IBL activities has an impact on the students' ability to verbalise their scientific knowledge and understanding. Thus, their views on their preferred language used were also sought during the interviews. The interviews were audio-recorded and then transcribed word for word. The interview questions can be found in Appendix 14. The transcripts of the pilot interview responses can be found in Appendix 15 while the main interview responses can be found in Appendix 16.

The interviews were piloted with two students, Reem and Liane, who had participated in the IBL activities at school but were not participants in the action research. Interviewing these two students for the pilot phase was deemed the best option as the responses obtained at this stage were from students with different attitudes toward the lessons as well as in their preferred language. Reem and Liane were asked to participate in the interviews for specific reasons: Reem always showed interest and participated in class, whether the lesson was mainly composed of a discussion, the teacher carrying out a demonstration, students carrying out an experiment in groups, engaging in an inquiry-based learning activity and when exam type questions were worked out. Reem could be considered a parallel monolingual as she was confident in expressing herself both in English and Maltese. On the other hand, Liane only participated eagerly during the discussions, inquiry-based learning activities and carrying out experiments in groups. She barely participated during the lessons when demonstrations were led by the teacher or when the lesson required working out exam type questions. Furthermore, Liane was a first-language Maltese speaker and preferred speaking in Maltese. Their responses to the interview questions can be found in Appendix 15. The group of students that was chosen for the analysis of the activities carried out was composed of five students, however only three students were willing to be interviewed.

My first intention was to carry out a group interview as it would have been less time consuming. However, on reflecting, I was concerned that the students could have felt uneasy sharing their actual views and opinions. They could also influence each others' responses. Hence, one – to – one interviews were carried out. Each interview took around forty-five minutes. Looking at the two students' responses I decided to keep the same questions and I was set to implement the interviews.

The students who participated at the pilot stage of the interview as well as in the actual interview were approached to be interviewed, were informed that the aim of the interview was to find out how students view learning Physics and that pseudonyms would be used so their identity would be kept totally confidential. They were also informed that only I as the researcher would have access to the audio-recordings and that they could opt not to reply to any question. They were reminded of these conditions prior to the interview. I also expressed my appreciation for their participation in my personal study and for the teaching and learning of sciences, mainly Physics in the Maltese state schools. The students provided written consent.

The interviews were semi-structured and consisted of fourteen questions. The first question was directed at finding out the students' views prior to Year 9, that is, before they started learning Physics. This served as an ice-breaker. Questions 2 and 3 focused on the students' preferred language (Maltese or English or both) used during the discussion and their preferred language to express themselves. Question 4 focused on their preference of the teacher's language and the language used in the classroom both by the teacher and themselves. Question 5 sought the students' views about talking/discussing in the Physics classroom. Questions 6 and 7 focused on their views about scientific language and their preferred way of learning scientific terminology. Question 8 probed their opinions about the writing used in Physics. Questions 9 – 12 were then specifically designed to obtain the students' views on how they feel when they are doing physics, their preferred type of lessons and the reasons for their preferences, how they felt during the first IBL activity and their current views on IBL activities. The last two questions, questions 13 and 14 were crucial to this study as the students' responses would provide an insight into whether they feel that IBL activities helped them learn Physics and their recommendations for effective teaching and learning in the Physics classrooms. The students' responses regarding their views on IBL activities and the language used in the classroom will be compared with the insights obtained from the analysis of the data collected during the IBL activities. This will provide a better picture on whether adopting an inquiry-based approach which is sensitive to language promotes better understanding of physics concepts and even on, whether creating classrooms which promote and value the use of different language repertoires, have an impact on the students' ability to express their scientific knowledge and understanding. The interviews were conducted at school during the mid-day break. The interviews were audio-recorded and then transcribed word-for-word.

The analysis of the interviews was based on thematic analysis, which is the process of identifying patterns or themes in the data that 'are important and interesting and use these themes to address the research' (Maguire and Delahunt, 2017, p.3353). In this case, it required identifying themes related to effective teaching and learning of Physics, the use of IBL activities, the language used during the lessons, the use of scientific terminology and the role of the teacher. Careful attention was given during the analysis to the students' responses to avoid the common pitfall of using the main interview questions as the themes (Braun and Clarke 2006; Clarke and Braun, 2013). Using the main interview questions is considered a weakness, as the themes would lead to the data being summarized and organized, rather than analysed (Maguire and Delahunt, 2017) and certain aspects could be missed. The findings that emerged from the students' responses to the interview questions are presented in Chapter 7.

5.4 Concluding Remarks

This chapter started by presenting the research design adopted during Cycle Two of this study, which is also based on an interpretive approach to research and action research. The data collection process and the research tools adopted for the data collection process were also discussed. The way that the codes were planned to guide the analysis of Cycle Two in finding out whether the students' language preference influences their choice of language to use and whether adopting a bilingual approach supports students in the construction of knowledge were also presented. The next chapter thus provides detailed descriptions of the three activities implemented in Cycle Two, alongside the analysis of each activity in detail, which will look closely at whether the students spoke entirely in English, entirely in Maltese or code-switched as they tried to make sense of the concepts and context they were presented with. The next chapter also presents the insights obtained on the effectiveness and promoting discussion of scientific concepts through IBL, interwoven with the influence of language use from the perspective of bilingualism.

Analysis
Cycle Two

6.0 Introduction to the chapter

This chapter presents the context and the data analysis of Cycle Two of the study. Cycle Two was partly carried out during the scholastic year 2017-2018, when the students were in Year 10 (their second-year learning Physics as a compulsory subject) and partly during the scholastic year 2018-2019. This chapter also describes the inquiry-based activities that I implemented in class with my students and the research methodology used as part of the data collection process. The detailed analysis and the main outcomes of this cycle of the research are presented. The last part of the chapter highlights the research keys and their main implications to my practice.

6.1 The focus of the second cycle of this action research

The main outcome of the analysis of Cycle One highlighted the issue that there might be a language barrier which may be interfering with the students' learning process. In the first cycle of the data collection, I strictly adhered to the use of the English language, instructing my students to only communicate in English and not Maltese. This meant that some of the students did not talk much. Therefore, the language barrier may very well have limited their participation and thus their contributions to the discussions. For this study, a contribution is understood to be a statement or opinion put forward by the student. Thus, each time any of the students expressed themselves was considered a contribution put forward to the discussion. In the first cycle, most of the discussions were initiated by myself as their teacher. This resulted in a question and answer sequence, aimed at encouraging the students to reflect on what they had observed and to also reflect on the scientific concept they were engaging with. There was limited student talk and consequently less social construction of knowledge taking place. Since inquiry-based learning strategies are described as a 'gateway for using language to speak' (Huerta and Jackson, 2010, p.207), it was expected that adopting an IBL approach would encourage the students to talk. However, their contributions to the discussion were very limited during Cycle One as they struggled with finding the right words to express themselves. This was understandable as some of my students were not that fluent in English as it was not their preferred language. These findings made me realise that, for my students to participate in the discussions, they not only needed to understand the content and engage in an IBL setting, but I also needed to consider the impact the language used was having on their ability and willingness to verbalise their scientific knowledge and understanding. In short, I needed to explore if they were more likely to engage in discussion and increase their social construction of knowledge if they used a language they were comfortable with and which they could use without being self-conscious. I could also do this as the Education Officer from the Ministry was allowing teaching of Physics with interspersed use of Maltese, even though assessment remained in English. Thus, I decided that for Cycle Two, I needed to focus on the use of language during lessons. This led me to refine my research question for Cycle Two to become:

- How does a bilingual approach impede or support students in constructing knowledge of physics concepts in a linguistically-mixed group?

I thus decided to change my strategy on the use of the English language in Cycle Two. Contrary to Cycle One, during the three IBL activities carried out during Cycle Two, the students were encouraged to freely express themselves in any of the two languages (English or Maltese) or a mixture of both, whichever they felt more comfortable with when expressing themselves. This decision was based on literature which shows that when students are not allowed to use their first language, it implies that the students 'can only use a limited part of their resources to make meaning' (Charamba, 2020b, p.665). It was also based on literature which shows that a monolingual pedagogy is a key factor in bilingual and multilingual students' academic underachievement in science exams (Charamba, 2021: Ünsal, et al*.,* 2018). These studies demonstrate that bilingual and multilingual students should be enabled and encouraged to use all available language repertoires in class. Research shows that, the use of students' mother tongue promotes a deeper understanding of the science concepts, resulting in improved academic performance. Thus, monolingual exams may limit bilingual students' achievement in science. Studies concerning bilingual students' language use in science classes have mainly been conducted in settings where both the teacher and the students speak the same minority language and the students are emergent bilinguals. In some studies, the teachers were also English second language speakers who did not speak the students' first language. The study underpinning this thesis is different from other studies concerning bilingualism as I speak the students' first language and I am also fluent in English (the second language).

This study draws on the above findings: the use of inquiry-based learning approaches and the use of the students' mother tongue to promote better understanding of physics concepts. Thus, this study looks at whether the next three IBL activities implemented in a bilingual setting with students who are not emergent bilinguals, promotes better understanding of scientific concepts. It also looks at the relationship between the language used in the classroom, the students' proficiency in talking about scientific ideas and their understanding. The role of the teacher in these activities is also considered, to identify the educational support needed to enable the students to improve their proficiency in talking physics. The students would at least be able to demonstrate their conceptual understanding and talk about phenomena even without specialized vocabulary (Harlow and Otero, 2006). The specialised vocabulary here refers to technical language, often referred to as scientific language or language of science. The technical terms have a specific meaning in Physics, which is diverse from their everyday meaning (Farrell and Ventura, 1998). In this study, students' use of specialised, technical language, is referred to as using scientific language.

The section below provides a description of the three IBL activities implemented during Cycle Two.

6.2 Research Design and implementation of Cycle Two

During this cycle, the three IBl activities were designed with the first activity involving a structured inquiry. While the students had started getting used to the IBL approach in Cycle One, where the students had more space to contribute to the learning process, they still needed to get used to it. As is characteristic of inquiry, all the activities were still based on a question or a challenge which the students had to investigate and find answers to the physics concepts being tackled. I used a worksheet for each activity to guide the students during their work in groups. The worksheets for the three activities can be found in Appendix 8, Appendix 10 and Appendix 12, respectively.

The second cycle also involved the implementation of 3 inquiry-based learning activities on the topics:

- Energy and Work Done,
- Light, and
- Forces.

The first two activities were planned to be carried out over one double lesson, that is, over 80 minutes (two consecutive lessons of 40 minutes each). The third activity was planned over two double lessons, that is, over 160 minutes. The process of the investigations was based on observations, recording data, and analysing the results to compose an explanation. The inquiry activities took place during practical sessions, and consequently in a laboratory. During these activities, the students worked in groups where each group was placed at a large desk where they could discuss and plan the activity, carry it out, discuss their results and draw their conclusions. As the teacher, I stood in the middle of the groups at the beginning of each activity to reach out to every group. During the activities, I went around the desks to assist and guide the students when the need arose. A new student had also joined my class. He worked well with the four students who had participated in the first cyce of this action research study.

The activities carried out in Cycle Two were audio-recorded. Audio-recordings of the activities were transcribed word for word. Non-verbal gestures and my interventions to guide and help students construct their own meaning were also noted as field notes. Ethical issues for this study were also taken into consideration and are presented in the section 3.7.

I carried out the activities over a period of one scholastic year, between November 2017 – May 2018 as follows: 1st activity in mid-November, 2nd activity in mid-February and the 3rd activity in mid-April. The data sources included:

- ***Field notes from lessons*** at the end of each IBL activity (focusing mainly on the type of questions I asked: to elicit what the students think, to elaborate on previous answers, to guide and help students construct their own meaning (Chin, 2006))

- ***Three audio-taped class conversations*** which included the introduction of each activity, any whole class discussions that took place as well as the conversations among target group during group work, which were then transcribed word for word.

The section below discusses the linguistic diversity during the activities implemented.

6.3. The linguistic diversity during the activities implemented

In this cycle I focused on the impact of language use in the three activities. I analysed the language (English and/or Maltese) which the students used at particular points, of the IBL activities. The analysis focused on the students' preference of language use and proficiency in talking when sharing their scientific ideas and demonstrating their understanding.

In order to analyse the language use, I first identified the overall linguistic strengths and preferences of the students. This helped me map the varying linguistic competences within which I, as the teacher, was operating while collecting my data in the particular context of the three inquiry activities implemented. The group consisted of five students from whom contributions were gathered during the data collection process. Out of the five students, there was one foreign student (Yuri) from Eastern Europe. Yuri had been in Malta for 5 years and could understand Maltese well, but he preferred to express himself in English. Both his parents were university graduates. The other students in the group (Matthew, Keith, Noel and Robert) were all Maltese and were mainly Maltese speaking. The mothers of Noel and Keith were both educators and their fathers were university graduates. The mothers of Robert and Matthew were housewives and their fathers had manual jobs: mechanic and truck driver respectively. Two of these Maltese students (Keith and Noel) possessed a very good level of vocabulary (Level B2 on the Common European Framework of Reference for Languages (CFER)) and were thus more proficient than the others in the English language. I concluded this by evidencing their ability to engage in discussions in English as well as in their writings during the Physics lessons and also because they obtained good grades in their English examinations (high achievers) as well as in other subjects which are assessed in English. The other two students (Matthew and Robert) had enough language knowledge to get by but struggled to express themselves fully in English (somewhere between A2 and B1 on the CFER), making them uncomfortable using English. I concluded this by evidencing their struggles to express themselves in English and due to the fact that both students did not perform well, either in English or in other exams assessed in English. The literature I revisited emphasizes the distinction between having enough language knowledge to get by (language used in everyday conversations) and the language of the classroom because the language used in everyday conversations 'can be described as relatively simple and concrete' (Charamba, 2020b, p.665) while the language of the classroom requires 'technical vocabulary' (ibid., p.665) as well as 'more complex grammar structures' (ibid., p.665). Thus, the overall linguistic diversity of the classroom was one where all the students understood the Maltese language, with one foreign student preferring not to speak it and all students understood English with two first language Maltese speakers struggling to find the right words to express themselves in English in the classroom.

As their teacher, I am a Maltese speaker with an excellent level of proficiency in the English language and have no problem expressing myself in any of these two languages (level C2 on the CFER). Although I feel comfortable expressing myself in both languages, I do, however, have the tendency to code-switch as I speak and switch from one language to another when engaged in informal discussions with colleagues and with the students during break time. However, in Cycle Two I was careful to adhere to speaking in English during class discussions and explanations but only resorted to code-switching when I noted that some students could not grasp the content I was explaining.

In order to research the role and impact of language use on learning, in these three activities the students (as opposed to the first cycle of inquiry activities) were encouraged to discuss in their preferred language (exclusive English or exclusive Maltese or a mixture of both languages). The activities were all audio-recorded and transcribed so that the use of language during the different activities could be analysed with respect to the research question set.

A first snapshot of language use can be obtained by tallying the different language use of the students' contributions over the three activities: English; Maltese; or code-switching, which refers to the alternating use of more than one language in the same contribution. Table 6.0 presents the number of contributions made by the first language Maltese speakers according to these three different language repertoires, when interacting among themselves as well as with the teacher during the three activities. The percentage of the contributions put forward by these students were calculated by looking at how many contributions were put forward by the four students in English, Maltese and by code-switching out of the total number of contributions they put forward altogether. Yuri was not included at this point as all his contributions were in English.

Table 6.0: *Use of different language repertoires by first language Maltese speakers*

	English	Maltese	Code-switching
Activity 1	17 (31.5%)	12 (22.2%)	25 (46,3%)
Activity 2	27 (32.9%)	19 (23.2%)	36 (43.9%)
Activity 3	11 (19.0%)	21 (36.2%)	26 (44.8%)

The above table shows that the first language Maltese speakers made use of the three different language repertoires during the three activities. However, the dominant language repertoires they used were code-switching followed by English. The use of code-switching was dominant during the three activities. There was an increase in the use of Maltese and a decrease in the use of English during the third activity. This implies that the lesson context, the type of inquiry (structured or guided/open) and the scientific topic tackled may influence the students' language use.

Since the students made use of either one language (English or Maltese) or a mixture of both (code-switching), the use of the different language repertoires used by each student during each stage of the 5 E's model of inquiry of the three activities was considered next. The contributions are presented for each of the three activities separately in the different tables presented in the below sections.

6.4 Design and implementation of the first activity of Cycle Two: Burning off the calories of a Mars bar

This activity, named 'Burning off the calories of a Mars bar' was a structured IBL activity, where the students were presented with an inquiry challenge related to forces and energy. This activity was a structured activity because it provided the students with the key inquiry question and the steps needed to follow during the investigation. This inquiry focuses on the relation of body weight and the work done, taking walking up versus running up a flight of stairs as a context. This activity was carried out over one double lesson. A double lesson was required because it allowed enough time for the task to be completed.

This inquiry-based learning activity was designed in the following 5E stages:

- ***Engagement***: Since this activity focused on the energy used while running up a flight of steps, the investigation was introduced by me writing the following question on the board '*Performing a 10-minute exercise will burn off the same number of calories for each and every one of us. True or False?*'. The students had to reflect on whether we will all burn off the same number of calories if we perform the same exercise for the same time. This introduction was chosen as I was targeting the physical relationship between force and energy. The Mars Bar example was also a context which the students were familiar with.
- ***Exploration***: The students were guided through the worksheet (Appendix 8) to carry out the investigation and guided to reflect on whether the same person would use more energy if the individual runs up the same flight of steps in less time and whether I or the students would generate more power. The students were provided with a measuring tape and weighing scales as during this stage, they also had to take the required measurement (the distance moved) to calculate their work done and their power individually.
- ***Explanation:*** The students had to explain the differences noted in their results from the investigation, that is, the work done and the power they generated. They had to discuss this in groups.
- ***Elaboration:*** This part of the activity was intended to enable the students to draw conclusions about whether performing the same exercise for the

same time would result in using the same amount of energy. They had to find this by calculating how many times they needed to run up the flight of stairs to burn off the calories of a Mars bar.

- ***Evaluation:*** The students' answers to the questions set in the worksheet, as well as their presentations enabled me to evaluate how the students understood the relationship between force and work done and how much learning took place.

This part of the Physics curriculum is based on the concept of work done, calculated as force multiplied by the distance moved in the direction of the force. The secondary level curriculum specifies that students are expected to know how to: calculate the work done using the formula Work done (W) = force (F) x distance (d) moved in the direction of the force; as well as its application of practical examples (SEC syllabus, 2022, p.13). This is why a practical activity was planned and implemented.

This activity was an IBL activity as it presented the students with a challenge which enabled them to hypothesize and test their ideas about whether everyone would burn off the same number of calories when performing the same exercise over the same amount of time. Since the students were already familiar with the terms: "energy", "fuel", "work done" and "power", they were expected to apply their previously acquired knowledge to explain the context that they were presented with. Therefore, this activity aimed at providing an interplay between the students' knowledge and ideas, and their observations of the context they were investigating. The aim was to help them realise that the energy used by different people when doing the same exercise varies, depending on their weight. Thus, different people need to exercise for different amounts of time to burn off the same number of calories.

6.4.1 Analysis of Activity 1: Burning off the calories of a Mars bar

6.4.2 Activity 1 – Engagement stage

There were very few exchanges, compared to the previous IBL activities, in the engagement stage of the first activity of this cycle. This was probably due to the session involving a teacher-led discussion. It was also the introduction to the theme. It was only one student from the group (Robert) who participated in this discussion. This highlights how the students spoke less when the discussion was led by the teacher.

Table 6.1a: *Activity 1 Engagement stage – language use*

	Name	English	Maltese	Code-switching	Total
Engagement stage: Introducing the relation between weight (force) and energy (work done).	Robert	0	0	3	3
	Noel	0	0	0	0
	Matthew	0	0	0	0
	Yuri	0	0	0	0
	TOTAL*1	**0**	**0**	**3**	**3**

(Keith was absent)

It is also interesting to note that in his three contributions, Robert used code-switching. The transcript of these occurrences is presented here below. KerryAnn was a student in my class who was also a foreigner. She had joined my class during her second-year learning Physics and participated in class-discussions. Although KerryAnn was an active participant during the class-discussion and interacted well with the participating group, her contributions were not taken into consideration in the analysis of the activities implemented in this cycle, as she was not part of the participating group. The words and/or phrases in bold red represent what the student said in English.

KerryAnn: No, definitely no. I go for a walk with my mum everyday as she is on a diet and she sweats a lot. I don't. So, she burns off more calories than me.

Robert: I think it is like a car. A **20 horsepower** Land Rover would use more **fuel** than a **20 horsepower** Toyota Yaris for the same distance.

Tch: Can you explain why?

Robert: A Land Rover is much heavier than a Yaris. A Land Rover is considered as a **heavy vehicle** while a Yaris is a **light car**. So, the Land Rover is like her mother and she is like the Yaris.

Tch: I understand your comparison. But can you explain why a Land Rover uses more fuel than a Yaris for the same distance?

Robert: The Land Rover is very heavy, so it needs more **fuel** to move forward as it has to carry a lot of **weight.**

It can be noted that in all the instances, Robert used the code-switching mainly to use terms which are related to Physics. The terms used: “fuel”, “20 horsepower”, “heavy vehicle”, “light car”, and “weight” are all specifically related to the physics situation being discussed. They are also everyday words e.g. it is common for Maltese people to use the word “fuel” in English when they go to fill up their car with petrol. The use of the words ‘*light car’* and ‘*heavy car*’ demonstrate that Robert is aware that English is the official language used to talk physics, as he is using these words to compare the use of fuel/energy by different sized cars with the fuel/energy used by people of different weight. In addition, making such a statement in Maltese by using Maltese words for “heavy” and “light” does not sound like physics because these words only have everyday meaning in Maltese.

The use of code-switching highlights how this student was more comfortable using Maltese to explain his reasoning but with the use of some words in English which are words that form part of the Physics repertoire and thus are considered as scientific language or words related to Physics. This keeps the exchange as part of Physics rather than everyday language.

6.4.3 Activity 1 – Exploration stage

The students made more contributions during the exploration stage of the activity. This highlights how the task managed to engage the students by posing questions and presenting different scenarios (Bybee et al., 2006) in reflecting about the physical context being considered, in this case, in considering how much energy is used if a person runs at a faster speed and in planning and carrying out the investigation.

Table 6.1b: *Activity 1 Exploration stage – language use*

	Name	English	Maltese	Code-switching	Total
Exploration stage: Reflecting on whether the same person would use more energy if the individual runs up the same flight of steps in less time.	Robert	4	4	10	18
	Noel	7	6	0	13
	Matthew	0	3	1	4
	Yuri	11	0	0	11
	TOTAL*2	**22**	**13**	**11**	**46**

I can note that my role as the teacher was a catalyst to eliciting these reflections by purposely designing the following questions in the worksheet: '*You and I run up the same flight of stairs in the same amount of time. Who does more work (uses more fuel)? State your reasoning*' and '*You run up the flight of stairs in a given amount of time. You run up the same flight of stairs in half the time. Would you do more work (use more fuel) or not? Explain your reasons*.' to the students. It is interesting to note that in this case all the students made contributions to the reflections. This shows that the students do participate in verbal exchanges when the activity invites them to contribute ideas and opinions.

During this exchange there was mainly a use of either English on its own or Maltese. The English contributions were made by Yuri, who usually speaks in English, and Noel. Noel mainly spoke either only in English, or only in Maltese. This shows that he has good proficiency in the use of both languages separately without any code-switching.

Considering the transcript provides more insight into what the students were reflecting on and how they changed their language repertoires.

Table 6.1c: *Extract 1 from the discussion during Activity 1 Exploration stage*

Turn Number	Utterance	IBL Main Code & Sub-Code	Language Use
1 Yuri	Reads question from worksheet: You and I run up the same flight of stairs in the same amount of time. Who does more work (uses more fuel)? State your reasoning.		
2 Noel	Does more work mean who burns off more calories?	SAsQ/ SAsQ-EvdL	English
3 Robert	Iva, juża aktar **fuel**, eżempju, bejn żewġ persuni, I – aktar wieħed li jiżen juża aktar **fuel**, bħal karozzi.	SRQ/ SRQ-EvdL	Code-Switching EvdL

	Yes, uses more **fuel**, for example, between two people, the heavier one uses more **fuel**, like cars.		

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The transcript above shows that the discussion started with Noel trying to understand the question, as it appears that Noel was not sure what '*burns more calories*' was referring to. This was followed by answers where Robert referred to the use of fuel and Yuri was more scientific by mentioning work. It is interesting to note that in this instance as the student used key scientific expressions, there was more use of English. The conversation then shifted to factors affecting the work done, with Yuri referring to the teacher's age.

Table 6.1d: *Extract 2 from the discussion during Activity 1 Exploration stage*

Turn Number	Utterance	IBL Main Code & Sub-Code	Language Use
4 Yuri	I think the teacher would do more work than us as she is older.	SRQ/ SRQ-EvdL	English
5 Noel	But there is nothing on the paper referring to her age.	SReb/ SReb-PEK	English
6 Robert	Jien naħseb li għandna nikkonċentraw fuq il – **body weight** mhux l – eta. I think we should concentrate on our **body weight** not age.	SLog	Code-Switching SL
7 Noel	So we should write that the teacher would use more fuel to go up the stairs as she weighs more than us as it would take her more time to run the flight of stairs.	SElb/ SElb-EvdL	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

Yuri's contribution in turn 4 reflects an alternative framework where he is confusing how tired and out of breath a person feels with the work done. Noel, being proficient in English, responds in English to point out that he thinks that age is irrelevant to the problem. This directs the discussion back to Physics, to which Robert suggests considering weight. Since Robert prefers Maltese, he reverts to code-switching, where as in the introduction, he only switches to English to make a specific reference to Physics, in this case '*body weight*'. Nonetheless, the conversation is flowing as the discussion becomes more elaborate. It is only Noel who at the end of this argument switches to English because he understands that English is the written language and he is suggesting what should be written. Thus, Noel switches to English to make an official scientific statement in response to the question in the worksheet.

Yuri put forward another idea, shifting the discussion from a focus on teacher's weight to stating that the energy used would be the same (Table 6.1e).

Table 6.1e: *Extract 3 from the discussion during Activity 1 Exploration stage*

Turn Number	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
8 Robert	Reads question from worksheet: You run up the flight of stairs in a given amount of time. You run the same flight of stairs in half the time. Would you do more work (use more fuel) or no? Explain your reasons.		
9 Yuri	I think the energy used would be the same.	SReb/ SReb-PEK	English
10 Matthew	Għala?* Why?	SAsQ/ SAsQ-Clr	Maltese
11 Noel	No. It would be more.	SReb/ SReb-PSK	English
12 Robert	Ikun anqas. Jekk tagħmel **exercise** għal **10 minutes**, ha taħraq aktar **calories** milli taħraq f' **5 minutes**. It would be less. If you **exercise** for **10 minutes** you will burn off more **calories** than you would in **5 minutes.**	SReb/ SReb-PSK SUKE/ SUKE-EvdL	Code-Switching EvdL
13 Yuri	But the work done is force times distance, so the person would have still used the same amount of energy, but in less time.	SReb/ SReb-PEK SUKE/ SUKE-SL	English
14 Robert	Ahh allura l – **energy used** tkun l – istess, vera, imma f'inqas ħin. Bħallikieku jien niġri **1km in 5 minutes** u nimxi **1km in 20 minutes**. Nuża l – istess **amount of energy** imma f'inqas ħin. Ahh so the **energy used** would be the same true, just in less time. As if I run **1km in 5minutes** and I walk **1km in 20minutes**. I would use the same **amount of energy** but in less time.	SAck-Aff SElb/ SElb-EvdL SElb-SL	Code-Switching SL
15 Noel	Mela niktbu dak li qal Robert. So we write what Robert said.	SLog	Maltese
16 Matthew and Yuri	Both nod in agreement.	SAck-Aff	------------------

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

Noel provided the corrective when Matthew asked Yuri to explain why he thought that the energy would remain the same. Robert could also make an argument, where, as in the previous case he used code-switching to explain how time could be a factor. As with his previous contribution he put his argument in Maltese and used key expressions in English to argue how '*exercise*' for '*10 minutes'* burns more *'calories*' than in '*5 minutes*'. While Yuri answered in English to point out that work done is calculated on the Force exerted and the distance, Robert rebutted his statement by again using code-switching. Robert translated Yuri's argument into the '*energy*' was the same as the distance was the same, referring to the example where one runs '*1km in 5 minutes*' and walks '*1km in 20 minutes*' would use up the same amount of energy. Again, Robert was code-switching when he demonstrated his conceptual understanding, that is, when he was talking physics. Robert, who keeps code-switching, now asks the meaning of '*generate more power*'. This is a Physics and not a language question (Table 6.1f).

Table 6.1f: *Extract 4 from the discussion during Activity 1 Exploration stage*

Turn Number	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
17 Robert	Ok. Xi tfisser **generate more power**? Ok. What does **generate more power** mean?	SAsQ/ SAsQ-SL	Code-switching SL
18 Yuri	I think that since power is the rate of using our fuel, it means who uses the fuel faster.	SRQ/ SRQ-EvdL	English
19 Robert	Qisu min jgħajja l – ewwel. As in who will get tired first.	SElb/ SElb-EvdL	Maltese
20 Yuri	Yes.	SAck-Aff	English
21 Noel	Anki jien hekk naħseb għax xi ħadd kbir ħa jgħajja aktar minn xi ħadd żgħir. Even I think so cause a heavy person would get more tired than a lighter person.	SElb/ SElb-EvdL	Maltese
22 Robert	Imma mhux għal ftit taraġ. But not for just a few stairs.	SReb/ SReb-PEK	Maltese
23 Yuri	But imagine if we had to do it 100 times?	SReb/ SReb-PEK	English
24 Robert	Mhux anki jien ngħajja jekk nitilghu mitt darba. But even I would get tired by doing it 100 times.	SReb/ SReb-PEK	Maltese
25 Noel	U huma jgħajjew aktar. And they would get even more tired.	SReb/ SReb-PEK	Maltese
26 Robert	Ok.	SAck-Aff	Maltese
27 Noel	So, the teacher would get more tired as she is heavier than us.	SUKE/ SUKE-EvdL	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

Yuri explains this in English as he refers to time. Robert now responds in Maltese, asking if Yuri is referring to who gets tired first. Robert here is using everyday reasoning rather than Physics, this potentially might explain why he did not code-switch as in his previous contributions put forward by code-switching, he was talking physics (making sense of the concept presented). The discussion now moves from Physics principles and the conversation continues mainly in Maltese as the students do not distinguish between the meaning of energy in Physics to its everyday use. It is only Yuri who contributed in English as at the end they conclude that the teacher will get more tired as she is heavier. From a Physics point of view, the students were engaged in conceptual work as they were exploring the concepts, yet their reasoning is yet not clear. This shows that the students have not yet arrived at clarity in relation to the scientific concept, which might reflect language interference as the Maltese expression 'without energy' is usually used to describe a person who is tired. Thus, in this case, the term energy in Physics which is equal to the work done is being used to reflect the meaning of feeling tired when one is '*without energy*', which shows that everyday and scientific concepts were not yet clearly distinct for the students. This is worth commenting on as a conceptual work-in-progress; however, the exposure of such cognitive conflict is also indicative of serious attempts to develop the scientific concept, and that will inevitably take time and repeated engagement with the scientific term.

The transcript below shows how the next part of this stage involved the students in deciding how to take the measurements that they needed for the investigation. The conversation focused on how to measure the height of the steps in the stairs and to calculate the total height, which units, cm or metres to work out the total height.

Table 6.1g: *Extract 5 from the discussion during Activity 1 Exploration stage*

Turn Number	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
28 Matthew	Kif ħa nkejlu l– għoli tat – taraġ? How are we going to calculate the height of the staircase?	SAsQ/ SAsQ-Log	Maltese
29 Robert	Inkejlu l – għoli ta **1 step** umbagħad nagħmlu **times** b'kemm hemm **steps**. We measure the height of **1 step** and then **multiply it** by the number of **steps**.	SRQ/ SRQ-EvdL	Code-Switching EvdL

30 Matthew	U jekk m'humiex kollha l – istess għoli? And if they are not of the same height?	SAsQ/ SAsQ-Clr	Maltese
31 Noel	Ejja mmorru barra u naraw jekk humiex tal – istess għoli l – ewwel. Let's go outside and see if they are of the same height first.	SLog	Maltese
32 Yuri	Miss, we are going outside. Can I take a measuring tape from the cupboard please?	SLog	English
33 Tch	Yes you can.	TchI/ TchI-RSQ	English
34 Matthew	Miss, ħabba li l – **height of 1 step** huwa inqas minn **metre** and u aħna ħa nkejluh f' **centimetres**, irridu naqilbuh għal **metres**? Miss, since the **height of 1 step** is less than a **metre** and we are going to measure it in **centimetres**, do we have to convert it in **metres**?	SAsQ/ SAsQ-Clr	Code-Switching EvdL
35 Tch	Why don't you see what your friends suggest?	TchI	English
36 Robert	Iva, **id - distance** dejjem inkejluha f' **metres**. Għadni kemm studjajt l - **SI units** u għad – **distance** and **length** nużghu **metres** u allura rridu naqilbuh. Yes, **distance** is always measured in **metres**. Just studied the **SI units** and for **distance** and **length** we use **metres** so we have to convert it.	SRQ/ SRQ-SL	Code-Switching SL
37 Yuri	True, True.	SAck-Aff	English
38 Robert	**Step** waħda hija **16cm**. 1 **step** is **16cm**.	SLog	Code-Switching EvdL
39 Noel	In metres?	SAsQ/ SAsQ-Log	English
40 Robert	0.16	SRQ/ SRQ-EvdL	English
41 Yuri	Yes, 0.16m.	SAck-Aff	English
42 Robert	Allura **0.16 x 10steps** huwa **1.6m**. Iktibha ħalli nidħlu lura fil – klassi. So, **0.16 x 10steps** is **1.6m**. Write it down so we go back in class.	SLog	Code-Switching EvdL

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

With the exception of Yuri, the students were mainly code-switching. This involved mainly speaking in Maltese and then including words in English to refer to the measurement type e.g. "height", "distance" and "length". They also used English words when referring to calculations. This is probably due to Mathematics being taught in English in Malta and so students really know how to count and work out calculations in the English language. The only contributions entirely in Maltese in this part were once by Noel and twice by Matthew, probably because in these contributions, the students did not use any scientific language. Having taken the measurements, the students set to calculate the work done. There was a short exchange with the teacher about the equations to use (Table 6.1h).

Table 6.1h: *Extract 6 from the discussion during Activity 1 Exploration stage*

Turn Number	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
49 Robert	Miss, we need to calculate our work done and power.	No MCode	English
50 Tch	OK	No MCode	English
51 Robert	How are we going to calculate our power?	SAsQ/ SAsQ-Clr	English
52 Tch	How do we calculate our power?	TchI/ TchI-S	English
53 Robert	Work done divided by time taken.	SRQ/ SRQ-SL	English
54 Yuri	Oh, but we don't know how long it takes us to run the flight of stairs.	SLog	English
55 Tch	Can't you find out?	TchI/ TchI-S	English
56. Yuri	Yes.	SAck-Aff	English
57 Noel	Għandna bżonn **stopwatch**. Miss, ħa nerġgħu nohorġu barra. Hemm **stopwatch** fil – **cupboard**? We need a **stopwatch**. Miss, we are going out again. Is there a **stopwatch** in the **cupboard**?	SLog	Code-Switching SL
58 Tch	Iva, hemm wieħed. Yes, there is one.	TchI/ TchI-RSQ	Maltese
59 Robert	Allura aħna kkalkulajna l – **work done** separati, **using the formula work done is force times distance moved**. So, we calculated our **work done** separately, **using the formula work done is force times distance moved**.	SLog	Code-Switching SL
60 Noel	Kollha għandna riżultat differenti. We all got different results.	SObS/ SObS-EvdL	Maltese
61 Yuri	Duhhh. Of course, since our body weight is different.	SUKE/ SUKE-EvdL	English
62 Noel	(Giggles) I told you my observation. (Group giggles)		English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

In the brief exchange with myself, the students spoke in English. This reflects that the students are aware that the official learning language for Physics is English. It was only Noel and Robert who used code-switching. Noel did first when he was trying to sort out how they were to measure the time which they needed, to work out the power. He thus used words like "stopwatch" and "cupboard" which are words used commonly in everyday Maltese language. In addition, there is no word for stopwatch in Maltese. In Robert's case, as in previous occasions, he code-switched to English terms like "work done" and "force times distance moved" which are part of the Physics repertoire. After the students took the necessary calculations and measurements and calculated the power they generated, the teacher enquired about the students' choice of equation (Table 6.1j). The analysis of this stage shows that during the exploration stage, out of the 46 contributions the students put forward, the students mainly:

- discussed aspects of the task such as what to do and how to carry out the investigation (Slog – 9 times). *Example: Let's go outside and see if they are of the same height*;
- acknowledged by affirming contributions put forward by peers (SAck-Aff – 7 times). *Example: Yes*;
- rebutted everyday knowledge put forward by peers (SReb-PEK – 7 times). *Example: But not for just a few stairs*;
- replied to questions using everyday language (SRQ-EvdL – 5 times). *Example: We measure the height of 1 step and then multiply it by the number of steps*;
- elaborated on previously shared knowledge using everyday language (SElb-EvdL – 5 times). *Example: Even I think so cause a heavy perso would get more tired than a lighter person*; and
- asked questions seeking clarification about contributions put forward by peers (SAsQ-Clr – 4 times). *Example: And if they are not of the same height?*

The analysis of this stage also shows how the students used different language repertoires according to the discussion. Noel mainly spoke in English and switched to Maltese when the conversation was less scientific and thus, no scientific words were put forward in these contributions. Robert preferred Maltese, and only used English in the form of code-switching in instances where he was considering physics aspects and used solely English when interacting with myself. Matthew did not really participate in the discussion, as he only made four contributions, out of which three were in Maltese. This does not mean that Matthew was less involved or was necessarily learning less, but it means that evidencing of his learning during the group discussions was constrained.

6.4.4 Activity 1 – Explanation stage

This stage represents that part of the activity where the students had to explain the difference in their work done and the power they generated.

Table 6.1i: *Activity 1 Explanation stage – language use*

	Name	English	Maltese	Code-switching	Total
Explanation stage: The students had to explain the differences noted in their results from the investigation, that is, the work done and the power they generated.	Robert	1	0	2	3
	Noel	3	0	1	4
	Matthew	0	0	1	1
	Yuri	4	0	0	4
	Total *3	**8**	**0**	**4**	**12**

During the explanation stage, the students' contributions were either in English or by code-switching. Only 5 out of the 31 contributions were strictly in Maltese. All the students: Robert, Noel and Yuri contributed. Matthew appears to be a quiet person as even in this stage of the activity he only spoke once, and he did so to reply to my question.

Table 6.1j: *Extract from the discussion during Activity 1 Explanation stage*

Turn Number	Utterance	IBL Main Code & Sub-Code	Language Use
63 Tch	Why did you choose this formula?	TchI/ TchI-E	English
64 Yuri	We chose work done is force times distance moved because since we needed to find out how many times we need to run the flight of steps to burn off the calories of a Mars bar, and calories can be converted into Joules, work done is the energy used and is measured in Joules. We only thought of that.	SRQ/ SRQ-SL SUKE/ SUKE-SL	English
65 Tch	Did you all agree with Yuri?	TchI	English
66 Matthew	Wasalna għaliha flimkien, imma ma nafx eżatt għala. Issa li qed ngħidha, irjalzzajt li aħna nġorru l – **body weight** tagħna u **weight** huwa tip ta **force.** We arrived at it together, but I don't know exactly why. Now that I said that, I realised that we carry our **body weight** and **weight** is a type of **force**.	SRQ/ SRQ-SL	Code-Switching SL
67 Noel	Issa rridu nagħmlu **question 4**. Now we have to do **question 4**.	SLog	Code-Switching EvdL
68 Tch	Ok	No MCode	English
69 Noel	Reads question from worksheet: From your group, who used more fuel and who generated more power? Explain. ***(Hint: The distance moved was the same for each member of the group).***		

70 Robert	Matthew used more power. Does it mean that the slowest person used more fuel and generated more power Miss?	SObS/ SObS-SL SAsQ/ SAsQ-SL	English
71 Tch	How about you see what your friends think about this?	TchI	English
72 Robert	Għala Matthew **generated more power**? Why did Matthew **generate more power**?	SAsQ/ SAsQ-SL	Code-Switching SL
73 Noel	Our fuel is our energy and work done is the energy we used to run up the stairs.	SRQ/ SRQ-EvdL SRQ-SL	English
74 Yuri	Wait, wait. So, since work done is the energy we used, who, who has the largest value used more fuel. I think.	SElb/ SElb-EvdL	English
75 Robert	Oh. Iva. Vera Yuri, naqbel. Allura Matthew uża', **generated more power** għax **his work done was the largest** u mhux għax kien l – i**slowest**. Oh. Yes. True Yuri, I agree. So, Matthew used, **generated more power** because **his work done was the largest** and not because he was the **slowest**.	SAck-Aff SElb/ SElb-SL	Code-Switching SL
76 Noel	I don't know whether it is because he was the slowest or not, but definitely because he has the largest work done.	SUnS SElb/ SElb-SL	English
77 Yuri	So, we have to write that Matthew has the highest power from all of us. Robert used the least fuel because his work done was the least one.	S-Log	English
78 Noel	And the reason why Matthew generated more power was because of his large work done as if he was faster, he would have generated even more power.	SElb/ SElb-SL SUKE/ SUKE-SL	English
79 Yuri	True, cause if we divide his power by a smaller number, we get a larger answer for power.	SAck-Aff SUKE/ SUKE-SL	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

It is noted that it was only when I directed a question to Matthew that he answered. Similar to Robert, he spoke in Maltese, and code-switched by including Physics terms like "body weight" and "force". The exchange which followed involved a discussion of the results which the students obtained. Since they had different body weights they all had different amounts of work done. Robert continued to code-switch as he asked why some '*generated more work*'. The analysis of this stage shows that out of the 12 contributions the students put forward in their attempt to explain their observations and the data they collected, they used scientific language mainly when they:

- replied to questions either posed by myself as their teacher or by their peers (SRQ-SL – 3 times). *Example: Our fuel is our energy and work done* *is the energy we used, who, who has the largest value used more fuel. I think*;

- used knowledge to explain (SUKE-SL – 3 times). *Example: Cause if we divide his power by a smaller number, we get a larger answer for power*;
- asked questions seeking further scientific knowledge (SAsQ-SL – 2 times). Matthew used more power. *Example: Does it mean that the slowest person used more fuel and generated more power?*; and
- elaborated on previously shared knowledge (SElb-SL – 2 times). *Example: And the reason why Matthew generated more power was because of hislarge work done, as if he was faster, he would have generated more power*.

The analysis of this stage also shows that when the students discussed the results obtained, the discussion was mainly in English as Yuri and Noel tried to draw conclusions from their results. While Yuri spoke in English as he prefers this language, Noel spoke in English to make an official scientific statement in response to the question in the worksheet. This shows that because English is the written language and he is suggesting what should be written, he resorted to English, the formal language of assessment.

6.4.5 Activity 1 – Elaboration stage

The elaboration stage represents that part of the activity when the activity drew to a close and the students were trying to discuss the results and draw conclusions from the data that they had gathered.

Table 6.1k: *Activity 1 Elaboration stage – language use*

	Name	**English**	**Maltese**	**Code-switching**	**Total**
Elaboration stage: Drawing conclusions about whether performing the same exercise for the same time would result in using the same amount of energy used.	Robert	0	0	2	2
	Noel	1	0	0	1
	Matthew	0	0	0	0
	Yuri	2	0	0	2
	Total *4	**3**	**0**	**2**	**5**

The transcript overleaf shows how this activity involved the students trying to discuss the results and draw conclusions from the data that they gathered. The conversation focused on the relation between different body weights and the time required to burn off the same number of calories.

Table 6.1l: *Extract from the discussion during Activity 1 Elaboration stage*

Turn Number	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
80 Robert	Allura jfisser li jien naħraq il – **calories** aktar bil – mod għax il – **mass** tiegħi inqas? So, it means that I burn **calories** slower because I have a smaller **mass**?	SAsQ/ SAsQ-CL	Code-Switching SL
81 Yuri	Yes Robert. A person with a small body weight has to run more or exercise more to burn off the calories.	SRQ/ SRQ-SL	English
82 Robert	Allura għall – aħħar biċċa rridu niktbu li t – **teacher** trid tiġri t – taraġ inqas drabi minnha kollha għax il – **weight** tagħha huwa aktar minn tagħna, sewwa? So, for the last part, we have to write that the **teacher** has to run up the stairs fewer times than all of us since she **weighs** more than any of us, right?	SUKE/ SUKE-SL	Code-Switching EvdL & SL
83 Yuri	Yes, and we add that because she weighs more, she generates more power.	SElb/ SElb-SL	English
84 Noel	Not necessarily. It depends on how fast or slow she is. So, our conclusion should be that since the teacher weighs more than us, she uses more energy to run up the stairs. So, will need to run the stairs a smaller number of times than we do. Burning of calories is the amount of energy used, not power generated.	SReb SUKE/ SUKE-SL	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

Robert kept code-switching as he engaged in the discussion and argued that his work done was less due to his lower weight. He was also able to contribute an answer to the teacher's initial question, applying the results about how the weight affects the work done and applying it to the teacher's context. The last part of the conversation then focuses on the final answer to be written, this still eliciting further discussions on the relationship between power and work done. Matthew once again appears to be a quiet person as in this stage of the activity he did not speak at all. This does not necessarily mean that Matthew was less involved or was learning less, but it means that evidencing of his learning during the group discussions was constrained. Although it might have been the case that he was struggling to understand the scientific concept, I believe it was more of a combination of being the quiet type and limited proficiency in the English language, as pointed out in section 3.5. Noel only contributed to the discussion once, to suggest what their conclusion should be.

The analysis of this stage shows that the students made use of scientific language in most of the contributions they put forward. Out of the 5 contributions the students put forward, they mainly used scientific language when they:

- used knowledge to explain (SUKE-SL – 2 times). *Example: …the teacher has to run up the stairs fewer times than all of us since she weighs more than any of us*; and

The analys also showed that similar to previous instances, when suggesting what to write, Noel speaks entirely in English in order to respond to the formality of writing and assessment in English and Robert code-switches, using English for words which are part of the Physics repertoire.

On analysing this experience, I concluded that:

- ***Presenting a structured IBL activity engaged the students more:*** This IBL activity was straightforward as a structured IBL activity as it provided the students with the key inquiry question and the steps needed to follow during the investigation. These made it easier for the students to understand what they had to do and what they needed to investigate. The students were also evidently getting accustomed to the IBL approach. They were thus more engaged when carrying out the investigation.

- ***The students understood well the relationship between weight (force) and work done (energy)*****:** The aim of this activity was to implement an IBL activity which enables the students to understand the relationship between force and work done and also to understand that the amount of calories burnt during an exercise depends on the weight of the person as well as on the time taken to perform the exercise. The students managed to explain fully their observations during the investigation. This meant that the students achieved a good level of understanding, as I had planned.

- ***There was more talk during the activity:*** The most dramatic difference from Cycle One was the significant improvement observed with respect to the students' talk during the activity, both during the investigation, as well as during the plenary. While I can consider that there was a significant improvement in the degree of talk taking place and an improvement in learning, this improvement was still not observed in all the students participating in the study.

- ***The students' language preference appears to influence their choice of language to use:*** Yuri stuck to speaking in English. Robert preferred Maltese and code-switched when referring to physics aspects. Noel tended to speak in English when talking physics and suggesting what to write in response to the questions in the worksheet and resorted to Maltese when interacting directly with Robert and Matthew. This showed that while there was an increase in talk, all the students reflected their language proficiency.

Collating my reflections and evaluation using Kolb's cycle, Table 6.1m below presents a summary of my experience before the first activity was carried out, my reflection on the outcomes of the IBL activity, the hypotheses that emerged from the analysis, and my plan for the second activity in this cycle.

Table 6.1m: *Research design following Kolb's cycle of reflection – Cycle 2 Activity 1*

Stage 1: Experience	From the first IBL activity during this cycle, I noticed that presenting the students with a structured IBL enabled them to engage in more discourse. I also have to keep in mind that the students were older as well as by now also familiar with IBL. While I can consider that there was an improvement in the degree of talk taking place, this was not observed in all the students participating in the study I also noted that their language preference appeared to influence their choice of language to use. They were also able to use scientific terminology – work done, force and power – well in their responses.
Stage 2: Reflections	This structured IBL activity shows that the students were becoming more accustomed to IBL. The students were able to demonstrate their learning and attempted to present explanations, using correct technical terminology. Allowing the students to express themselves in their preferred language allowed more discussions and social construction of knowledge to take place.
Stage 3: Generalisations/ Hypotheses	The more students experience IBL activities and are afforded opportunities to use their preferred language, the more they learn to talk and engage in social construction of knowledge. They will learn physics concepts better as well as learn how to express themselves in correct scientific way.
Stage 4: Plan	I thus planned to implement another structured inquiry-based learning activity where the students were again to be allowed to use their preferred language. The activity was to be designed to look closer at whether a bilingual approach supported students in the construction of knowledge and whether there was a relationship between the language (English, Maltese or code-switching) used in the classroom and the students' frequency and proficiency in talking about scientific ideas during the learning process.

The reflections and evaluations of this activity fed into the methodology for the second activity of this cycle. With the above research design in mind, the second IBL activity of this cycle was planned.

6.5 Design and implementation of the second activity of Cycle Two: Exploring Light through Prisms

Based on my reflections on Activity One of this cycle, I planned another structured IBL activity, this time on the topic of Light. The students were presented with an inquiry related to the dispersion of white light on the surface of bubbles. Colours are formed over the soap bubble's surface when light falls on its surface. The spectrum observed represents the multiple refractions that occur when white light gets split into its seven component colours. This phenomenon is known as dispersion of white light. The activity did not go into the physical phenomenon of interference which results due to the multiple refractions as this is not included in the Physics secondary syllabus. The aim was to introduce and target the phenomenon of dispersion of white light. This activity was implemented over one double lesson, a total of 80 minutes. A double lesson was required because it allowed enough time for the task to be completed.

This inquiry-based learning activity was designed in the following 5E stages:

- ***Engagement***: I introduced the investigation myself by blowing soap bubbles and asking the students to observe what happens to white light. The students were then invited to reflect on why we see colours when we blow bubbles, and whether the surroundings affect the colours "seen" in a bubble. The students also had to reflect in groups on whether they would still observe colours on the surface of the bubble, if everything in the classroom was painted white and they were all wearing white clothes.
- ***Exploration***: The students had to investigate the behaviour of light when white light passes through it. They had to predict what happens to the spectrum of white light when the distance between the prism and the sheet of paper is changed. They also had to set up the same apparatus as that on the teacher's desk to investigate what happens to white light when it passes through a triangular prism. This was then repeated using a single coloured filter or a combination of coloured filters placed in the path of white light between the ray-box and the prism. The students were provided

with a light bulb, a ray-box, sheets of paper, various coloured filters and a triangular prism. A triangular prism was used as it gives the best and tidiest result for clear dispersion of white light.

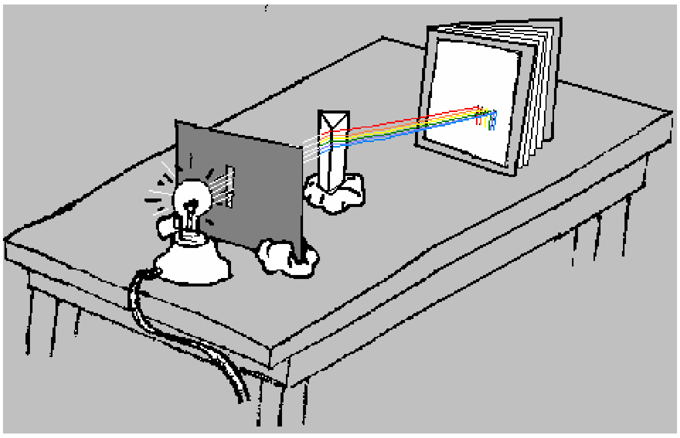


Figure 6.1: Apparatus displayed on teacher's desk for students to set up

- ***Explanation:*** The students had to explain how white light behaved when it passed from one medium to another and what was causing the change. The intention was for them to notice that the white light is dispersed in the separate colours when the white light passes from one medium to another.
- ***Elaboration:*** This part of the activity was intended to enable the students to draw conclusions about white light when it passes from one medium to another and when a single coloured filter or a combination of coloured filters is placed in the path of white light.
- ***Evaluation:*** The students' answers to the questions set in the worksheet, as well as their presentations enabled me to evaluate how the students understood the phenomenon of dispersion of white light and whether their experience in engaging in IBL activities was enough to move to less structured IBL activities.

This part of the Physics curriculum focuses on the concepts of refraction and dispersion of white light. The physics of reflection and refraction had already been tackled and observed through practical work during previous lessons. However, the concept of dispersion of white light into separate colours had not yet been covered. The Physics SEC syllabus at secondary level does not expect the students to interpret dispersion of white light as dependent on the different wavelengths. It only expects students to 'give a qualitative account of the dispersion of light as illustrated by the action on light of a glass prism' (SEC syllabus, 2022, pg. 24). Thus, the students only needed to understand and interpret qualitatively that light is refracted when it passes from one medium to another and that colours are produced as the beam of light changes direction differently for the different colours. This is why a practical activity that the students are familiar with (seeing colours on a bubble's surface) but unfamiliar with the physical phenomena at play, was planned and implemented.

6.5.1 Analysis of Activity 2: Exploring light through prisms

6.5.2 Activity 2 – Engagement stage

The main part of this stage was to introduce the phenomenon of colours observed on bubbles and the activity which was then to follow. It involved blowing actual bubbles in class so that the students could notice the colours on their surface and inviting them to reflect on why it was possible to see these colours on the surface. This example was chosen as it involved dispersion of white light which was the physics phenomenon to be considered. The concept of dispersion had not yet been explained to the students as I wanted them to work on it themselves. As in the case of Activity 1, this part was a teacher-led class discussion. The number of students' contributions in this activity increased compared to the engagement stage of Activity 1. This was probably due to the students becoming more used to engaging in teacher-led discussions. It may have also possibly been because the students were tackling a context that they were familiar with: colours on the surface of the bubble, a phenomenon which they may have encountered in everyday life. During this activity, Matthew (a first language Maltese speaker) and Yuri (the foreign student) were absent. The other three students whose first language preference was Maltese, made use of the three different language repertoires. In fact, Robert mainly code-switched and spoke entirely in Maltese, while Noel and Keith spoke either entirely in English or by code-switching.

Table 6.2a: *Activity 2 Engagement stage - language use*

	Name	English	Maltese	Code-switching	Total
Engagement stage: Introducing dispersion of white light by blowing soap bubbles and reflecting on why we are able to see colours when we blow bubbles, and whether the surroundings affect the colours "seen" in a bubble.	Robert	1	5	7	13
	Noel	3	1	4	8
	Keith	5	1	4	10
	Total *1	**9**	**7**	**15**	**31**

(Yuri and Matthew were absent)

At the beginning of this stage, the students had to report their observations every time I blew a bubble. They also had to provide an explanation of what was happening in their observation. The transcript of these exchanges is presented here below (Table 6.2b).

Table 6.2b: *Extract 1 from the discussion during Activity 2 Engagement stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language
1 Tch	Look at the bubble, what can you see?	TchI/ TchI-E	English
2 Noel	Colours.	SRQ/ SRQ-ObS	English
3 Tch	Which colours can you see?	TchI/ TchI-E	English
4 Robert	Rainbow colours.	SRQ/ SRQ-ObS	English
5 Noel	So, we write rainbow colours?	SAsQ/ SAsQ-Log	English
6 Tch	Remember that you have to discuss, explain and agree first, then you write down the answer.	TchI	English
7 Robert	Naħseb irridu niktbu l – kuluri li rajna. I think that we have to write down the colours we saw.	Slog	Maltese
8 Noel	Eżatt, mhux il – kuluri kollha, dawk li rajna biss. Exactly, not all the colours, just the ones we saw.	SAck-Aff	Maltese
9 Keith	So, we write, Red, Orange, Green, Blue, and pink?	SAsQ/ SAsQ-Log	English
10 Robert	Jien ma rajntx **pink** u int insejt isemmi li rajna **yellow**. I didn't see **pink** and you forgot to mention **yellow**.	SRQ/ SRQ-ObS	Code-Switching EvdL
11 Noel	U **purple**. And **purple**.	SObS/ SObS-EvdL	Code-Switching EvdL
12 Robert	Kienet qisha **rainbow**, allura rajna aktar **colours**. It looked like a **rainbow**, so we saw more **colours**.	SObS/ SObS-EvdL	Code-Switching EvdL
13 Noel	Iva kienet qisha **rainbow**. Yes, it looked like a **rainbow**.	SAck/ SAck-Aff	Code-Switching EvdL

14 Keith	Can we do another bubble Miss please?	SAsQ/ SAsQ-Log	English
15 Tch	Yes sure. The solution is here.	TchI/ TchI-R	English
16 Robert	Ara, nista nara aħmar, oranġjo, ftit isfar, aħdar, blu u żewġ **shades of purple**. Look, I can see red, orange, a bit of yellow, green, blue and two **shades of purple**.	SObS/ SObS-EvdL	Code-Switching EvdL
17 Noel	Iktar qisu **violet**. More like **violet**.	SObS/ SObS-EvdL	Code-Switching EvdL
18 Robert	Huma l – istess. They are the same.	SReb/ SReb-PEK	Maltese
19 Keith	Le, dawk huma **indigo** u **violet**. No, they are called **indigo** and **violet**.	SReb/ SReb-PEK	Code-Switching EvdL
20 Robert	Int għandek **Arts option**, allura int taf aktar fuq il - **colours**. You have **Arts option**, so you must be right about the **colours**.	No Main Code	Code-Switching EvdL
21 Noel	So, we write red, orange, yellow, green, blue, indigo and violet or violet and indigo?	SAsQ/ SAsQ- Log	English
22 Keith	Indigo and violet.	SRQ/ SRQ-ObS	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

Although, I (their teacher) had stated '*Remember that you have to discuss, explain and agree first, then you write down the answer*' when Noel questioned whether they should write '*rainbow colours*' in the worksheet, the students focused mainly on reporting their observations. The discussion thus focused mainly on identifying the different colours observed rather than trying to explain why they noticed the colours of the rainbow on the bubbles' surface.

From the perspective of language use, the students' first exchanges were in English in response to my questions which were in English. However, this changed with Robert's contribution, which was completely in Maltese as he asked about instruction on what they had to write. Noel and Robert spoke entirely in Maltese as they interacted with each other and discussed what to write in response to the question set. At this point, the students were not reasoning as they were discussing what to write according to their observations. Robert only contributed once to the discussion entirely in English, where he reported that they had seen '*rainbow colours*' in his response to the question set. Keith and Noel, on the other hand spoke entirely in English when interacting with me, (the teacher). The overall pattern is that when interacting with me, the students mainly resorted to speaking entirely in English. Similar to Activity 1, Noel and Keith probably spoke entirely in English when suggesting what to write in order to respond to the formality of writing and assessment which is in English.

The conversation then continued with the use of code-switching where the students identified the colours in English as they spoke in Maltese. This is a common everyday language occurrence in normal conversations in Malta. However, it could also reflect the students' consideration of the colour names as part of the language of physics, as this was consistent during each stage of this activity. It also highlights how these students were more comfortable using Maltese to explain their reasoning but with the use of some words in English which are words related to Physics.

Thus, the terms stated in English included: pink, yellow, purple, rainbow, colours, shades of purple, violet and indigo, all of which are specifically related to the Physics related to the colours in white light and in the rainbow.

In the second part of the engagement stage, the students were invited to reflect on why they had seen 'rainbow colours' by asking them to answer the following question in the worksheet (Appendix 10) '*Give a reason why you are seeing what you described in the previous question*'. The students took some time to reflect on this. There was only one contribution at this stage, by Keith, who shared his idea that '*Light reflects colours through the bubble*' with which the other group members agreed. This shows how at this instance the students were unable to rebut Keith's contribution or to put forward alternative explanations, even though the students were already familiar with the concepts of reflection and refraction. Thus, as their teacher, I expected the students to use their previously acquired knowledge about these two concepts to rebut Keith's idea. One possible reason could be that the students were still confusing the meanings of the concepts of 'reflection' and 'refraction'. Though I would have preferred the students to discuss this aspect further and in greater detail, I cannot say that they were not engaged in making an effort to try and provide possible explanations to the phenomenon being observed. It also has to be highlighted that I had not yet introduced the concept of dispersion where white light is separated into several colours. Thus, so far, this activity showed that the phenomenon was too complex for the students to explain without judicious scaffolding. The activity had not yet provided enough insights for them to figure out through direct observation, how light behaves when it passes from one medium to another, with opportunities to become aware of dispersion on their own. The students were then invited to reflect on whether colours would still be observed on the surface of the bubble, if everything in the classroom was painted white and they were all wearing white clothes.

Table 6.2c: *Extract 2 from the discussion during Activity 2 Engagement stage*

Turn No.	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
25 Noel	Reads question from worksheet: If everything in the classroom was painted white, and you were all wearing white clothes, do you still think we would see colors in the bubbles?		
26 Robert	Le, la m'hemmx kuluri mhu ħa jirrifletti xejn. No, because it won't reflect anything since there aren't any colours.	SUKE/ SUKE-SM	Maltese
27 Keith	Dażgur li iva. Il – **beam of light** huwa abjad. Yes, we would. The **beam of light** is white.	SReb/ SReb-PSK SUKE/ SUKE-SL	Code-Switching SL
28 Robert	Iva il – **beam of light** huwa abjad imma xejn ma jiġri. Yes, the **beam of light** is white but nothing will happen.	SReb/ SReb-PSK	Code-Switching SL
29 Keith	Imma meta l – **white light** daħal ġol – **bubble**, ħareg bħala **colours**, **different colours**. But when **white light** entered the **bubble**, it came out as **colours**, **different colours**.	SReb/ SReb-PSK SObS/ SObS-EvdL	Code-Switching EvdL and SL
30 Robert	Imma taf għala ħareg bħala **different colours**? Għax ġie **reflected**. Kieku kollox ikun abjad, xejn ma jiġi **reflected**. Allura le, l – **answer** huwa le. But do you know why it came out as **different colours**? Because they got **reflected**. If everything is white, nothing will get **reflected**. I think the **answer** is no.	SUKE/ SUKE-SM	Code-Switching EvdL and SL
31 Keith	Id – dawl xorta jigi **reflected**, ghax kieku ma narawx l – **objects**, imma ma jkun hemm **colours**. Light would still be **reflected**, otherwise we won't see the **objects**, but there won't be **colours**.	SReb/ SReb-PSK	Code-Switching SL & EvdL
32 Robert	Eżatt. Allura le, ma narawx kuluri. Exactly. So, no we won't see colours.	SAck-Aff	Maltese
33 Noel	Aħna ma rajnix il – **colours** fil – **bubble** għax id – dawl kien **reflected**. Jien naħseb, jien naħseb li kien aktar ħabba li l – **beam of light was passing from one material to another material**. Tagħmel sens għalikom? We didn't see the **colours** in the **bubble** because the light was **reflected**. I think, I think that it was more because the **beam of light was passing**	SReb/ SReb-PSK SUKE/ SUKE-SL SAsQ/ SAsQ-Clr	Code-Switching EvdL and SL

	from one material to another material. Does it make sense to you?		
34 Keith	Eħe, iva, bħal meta l – **beam of light was bent** meta għaddha mill – arja għas – **semi-circular glass block**, fl – **experiment** li għamilna. Ah, yes, like when the **beam of light was bent** on passing from air through **the semi-circular glass block**, in the **experiment** we did.	SAck-Aff SUKE/ SUKE-SL	Code-Switching EvdL and SL
35 Robert	Allura rridu nirranġaw l – **answer** u niktbu li aħna rajna l – **colours** fil – **bubble** għax il – **bubble bent the beam of light** u tagħtu l – **colours**. So, we have to amend our **answer** and write that we saw the **colours** in the **bubble** because the **bubble bent the beam of light** and it gave it **colours**.	SLog SUKE/ SUKE-SL	Code-Switching EvdL and SL
36 Keith	OK. Allura l – **light beam** tgħawweġ ħafna drabi? OK. So, the **light beam** bent several times?	SAck-Aff SAsQ/ SAsQ-SL	Code-Switching SL
37 Robert	Ma nafx. Ma naħsibx. I don't know. I don't think so.	SUnS	Maltese

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The transcript above shows how the students engaged in debate and the conversation among them focused mainly on the difference between the concepts of reflection and refraction. Robert (turn 30) was able to ask an authentic scientific question, which enabled the students to reflect and make connections between the physics knowledge that they had already learnt and the new phenomenon being observed. Thus, these interactions promoted better understanding of the concepts of reflection and refraction among the students. Furthermore, the social interactions during this part of the engagmenet stage, demonstrate that the students were willing to change their minds. The interactions also demonstrate their effort to make sense of the phenomenon being observed. However, the discussion was not enough for the students to realise that the beam of light bends several times and that is why a spectrum was produced. In fact, when Keith posed a question enquiring whether white light bends several times, none of his group members followed up on this statement. Despite this, it is noted that the students got much closer to the concept of refraction by the end of this exchange, which is substantial evidence of the potential of active and collaborative approaches to learning.

It is interesting to note that in this exchange, none of the students spoke entirely in English. This is possibly because I, as their teacher was not an active participant in the discussion, Yuri (the foreign student) was absent that day and it was Robert (who prefers Maltese) who suggested what to write as their answer to the question in the worksheet. In fact, the three first language Maltese speakers mainly code-switched. Similar to the previous activity, they used Maltese to explain their reasoning and resorted to English for key expressions often used in Physics. The analysis of the engagement stage shows that out of the 31 contributions put forward by the students, they mainly:

- reported directly what they observed using everyday language (SObS-EvdL – 5 times). Example: It looked like a rainbow, so we saw more colours;
- rebutted scientific knowledge put forward by peers (SReb-PSK – 5 times). *Example: Light would still be reflected, otherwise we won't see the object, but there won't be colours*;
- asked questions seeking logistical responses (SAsQ-Log – 4 times). Example: So we write red, orange, yellow, green, blue, indigo and violet or violet and indigo?;
- replied to questions by reporting directly their observations (SRQ-ObS – 4 times). *Example: Rainbow colours*;
- shared their knowledge to explain (SUKE-SL – 4 times). *Example: …I think that it was more because the beam of light was passing from one material to another material*; and
- acknowledged by affirming contributions put forward by peers (SAck-Aff – 4 times). *Example: Exactly, not all the colours, just the ones we saw*.

The analysis of this stage also shows how the students used different language repertoires according to the discussion. Keith spoke either entirely in English or code-switched. Robert preferred Maltese, and only used English in the form of code-switching in instances where he was considering physics aspects. Noel spoke mainly entirely in English and by code-switching. He spoke entirely in English to respond to the formality of writing and assessment in English and code-switched when interacting with the other group members. When code-switching, he explained his reasoning in Maltese but resorted to English for key expressions used often in Physics e.g. “experiment”, “glass block” and “beam of white light”.

6.5.3 Activity 2 – Exploration and explanation stages

This part refers to that part of the activity where the students: 1) were thinking about what would happen to the spectrum of white light when the distance between the spectrum produced and the glass prism was changed; 2) had to set up the same apparatus as that on the teacher's desk to investigate what happens to white light when it passes through a triangular prism; and 3) repeat the investigation using a single coloured filter or a combination of coloured filters placed in the path of white light between the ray-box and the prism.

Table 6.2d: *Activity 2 Exploration and Explanation stages - language use*

	Name	English	Maltese	Code-switching	Total
Exploration and Explanation stages: Reflecting on what would happen to the spectrum of white light produced on a sheet of paper as it is moved closer and further away from the prism. They also had to set up the same apparatus to investigate what happens to white light when it passes through a triangular prism.	Robert	5	4	8	17
	Noel	2	3	1	6
	Keith	5	2	4	11
	Total *2	**12**	**9**	**13**	**34**

I can note that my contribution as the teacher during the first part of the exploration stage elicited the students' reflections by purposely designing the questions set in the worksheet (Appendix 10, Part B). The three students made contributions to different degrees. This still shows that the students participated in verbal exchanges when the activity invited them to contribute ideas and opinions.

During this part of the exploration stage, there was mainly a use of code-switching. The English contributions were made once by Robert and once by Keith. Contributions in entirely Maltese were put forward by all the three students. Noel and Keith spoke entirely in Maltese when their contributions were directed at Robert. The transcript overleaf (Table 6.2e) presents the exchanges while the students were discussing what would happen to the spectrum in relation to the distance between the spectrum and the prism.

Table 6.2e: *Extract 1 from the discussion during Activity 2 Exploration and Explanation stages*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
42 Keith	Reads question from worksheet: What does your group think will happen to the spectrum as you move it away from the prism? Explain why.		
43 Noel	**Spectrum** huwa ħafna kuluri. **Spectrum** is a lot of colours.	SUKE/ SUKE-SL	Code-Switching SL
44 Robert	Kif ħa nispjegawha? How are we going to explain it?	SAsQ/ SAsQ-Clr	Maltese
45 Keith	Naraw ħafna kuluri mma mhux **bright**. We would see a lot of colours, but not **bright**.	SRQ/ SRQ-EvdL	Code-Switching EvdL
46 Robert	U jekk tressaqha viċin, il – kuluri ikunu **bright**. And if you move it closer, the colours would be **bright**.	SElb/ SElb-EvdL	Code-Switching EvdL
47 Noel	U iktar faċli tarafhom. And easier to distinguish.	SElb/ SElb-EvdL	Maltese
48 Robert	X'jiġifieri? What do you mean?	SAsQ/ SAsQ-Clr	Maltese
49 Keith	**Perfect red**, **perfect blue** u hekk. Ma nistax nispjegha sewwa. Meta nixgħelu l – **bulb**, nurik x'irrid infisser. **Perfect red**, **perfect blue** and so on. I can't explain it properly. When we switch on the **bulb**, I'll show you what I mean.	SUKE/ SUKE-EvdL	Code-Switching EvdL and SL
50 Robert	Allur aktar ma nressquha l – bogħod mill – **light bulb**, aktar ikunu **spead out**, le? Bħal meta tużha **flashlight** u d – **distance** hija kbira. So, the more we move it away from the **light bulb**, the more **spread out** they will be, no? Like when using a **flashlight** and the **distance** is long.	SAsQ/ SAsQ-Clr SUKE/ SUKE-EvdL	Code-Switching EvdL and SL
51 Keith	Eżatt. Għalhekk ma jkunux **sharp**. Qishom ikunu **blending** ma xulxin. Exactly. That is why they won't be **sharp**. As if they are **blending** with each other.	SAck-Aff SElb/ SElb-EvdL	Code-Switching EvdL
52 Noel	Qishom **smudged** wieħed fuq l – ieħor? Like they are **smudged** onto the next one?	SAsQ/ SAsQ-Clr	Code-Switching EvdL
53 Keith	Il – **beam of light** fit – tarf ma jkunx **strong**, allura naħseb li għandna niktbu li jekk inressqu l – i**spectrum** il – bogħod, l – i**spectrum** ikun **lighter**. Jekk inressquh viċin, l – i**spectrum** ikun **brighter and sharper**. The **beam of light** at the end of it won't be **strong**, so I think that we have to write that as we move the **spectrum** away, the **spectrum** would be **lighter**. If we move it closer, the **spectrum** would be **brighter and sharper**.	SUKE/ SUKE-SL SLog	Code-Switching EvdL and SL
54 Robert	It won't be strong and will be dimmer too.	SElb/ SElb-EvdL	English

* words written in Red denote English words used while speaking in Maltese
* words written in Blue denote Maltese words

The transcript above shows that the discussion started by a definition of spectrum, which was not sufficient for Robert to understand how they were going to answer the question in the worksheet. Keith attempted to explain the scientific term “spectrum” using everyday language. He even shared his prediction about what they would possibly observe.

The discussion became more elaborate as the students attempted to explain how the colours would be bright and easy to distinguish when the sheet of paper is moved closer to the prism. Robert demonstrated his reasoning by comparing the effect of the distance between the sheet of paper and the prism on the brightness of the colours produced, to a beam of light produced by a flashlight to see objects at a distance. Robert expressed himself entirely in Maltese when the conversation was less scientific and did not use any specialized technical words in these contributions. Keith and Noel on the other hand, mainly code-switched. They reasoned about what would happen to the spectrum in relation to the distance between the spectrum and the prism in Maltese and resorted to English for specialized technical terms and terms related to describing what was happening from a Physics perspective in the activity. As the students started using key expressions often used in Physics in English, there was also more use of the English language.

The transcript below (Table 6.2f) presents the students’ exchanges during the next part of the exploration stage, which required the students to discuss whether the beam of light is affected when passing through a triangular prism.

Table 6.2f: *Extract 2 from the discussion during Activity 2 Exploration and Explanation stages*

Turn No.	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
58 Robert	Reads question from worksheet: What do you think will happen to the beam after it leaves the prism? Explain your answer.		
59 Robert	Jista jkun li l – **prism** taħdem bħal **bubble**? Could it be that the **prism** acts like the **bubble**?	SAsQ/ SAsQ-EvdL	Code-Switching EvdL and SL
60 Keith	X’jiġifieri? What do you mean?	SAsQ/ SAsQ-Clr	Maltese

61 Robert	Ħa naraw **rainbow colours**. We will see the **rainbow colours**.	SUKE/ SUKE-EvdL	Code-Switching EvdL
62 Noel	Għala? Why?	SAsQ/ SAsQ-Clr	Maltese
63 Robert	Għax il – **beam** jgħaddi mill – **air** għal **prism**, u lura għal – **air**, allura **it bends**. Because the **beam** will be passing from **air** to the **prism**, back to **air** again, so **it bends**.	SUKE/ SUKE-SL	Code-Switching EvdL and SL
64 Keith	And on bending, it refracts different colours.	SElb/ SElb-EvdL	English
65 Robert	Eżatt. Exactly.	SAck-Aff	Maltese
66 Noel	Nods in agreement	SAck-Aff	---------------

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The exchange above shows how the students were able to engage in debate. The students were able to ask questions and provide explanations as they shared their hypothesis to explain what would happen to the beam of light. The discussion, in fact, started by a question aimed at seeking scientific clarification. Here Robert was trying to make connections between what they had observed and discussed during the engagement stage (seeing rainbow colours on the surface of soap bubbles) and the spectrum produced by the prism later in the activity. Both Keith and Noel questioned Robert's prediction that separate colours will be produced by the prism, similar to what was observed in the bubble. In his response to their questions, Robert attempted to explain his reasoning by making reference to his previously acquired knowledge about what happens to white light when it passes from one medium to another. This enabled Keith to understand that white light is refracted, and colours are produced. These social interactions among the students promoted better understanding of the concept of refraction. As a result of the social interactions taking place during this activity, the less knowledgeable learned 'through the assistance of another person' (Holzman, 2018, p.42) who was either the expert in the field or the more capable but functioning within the ZPD. Within this Vygotskian framework, Keith, the currently less knowledgeable student learnt by internalizing the knowledge presented by the currently more competent student (Robert). These social interactions also provided the students with an opportunity to understand how a spectrum is produced when a beam of light passes through a triangular prism.

This helped me evidence the students' learning as Robert was able to show that he had understood the concept of reflection well and it also helped Noel to show that he knew the difference between the concepts of reflection and refraction. In Noel's case, one can argue that he had either mistakenly used the terms interchangeably in his earlier contribution or it is evidence that word meaning develops (Vygotsky, 1987) and became clearer and deeper, with usage, and exposure to potential critique from his peers and teacher, over time.

When one considers, which language the students adopted during this exchange, as in the case of previous exchanges, they used only Maltese when the discussion was less scientific. In such instances, no technical words were used. In addition, any code-switching adopted while reasoning in Maltese mainly involved using English for specialized technical words and non-technical words related to the activity. Only Keith spoke entirely in English. This occurred once towards the end of the discussion when Keith tried to elaborate on Robert's contribution. As in Activity 1, this possibly reflected his effort to respond to the formality in writing and assessment, which is in English, as the students had to write down their answer on the worksheet.

The next part of the exploration stage required the students to engage in implementing the investigation and to observe what happens to white light when it passes through a triangular prism. They also had to observe how the beam of light behaves when a single coloured filter or a combination of filters is placed in the path of the beam of white light before it enters the prism.

The transcript below (Table 6.2g) shows how during this explanation stage, my role as the teacher was that of a catalyst in eliciting the students' reflections and explanation through questions that I posed to scaffold their thinking and to promote explanations. The conversation focused on the difference between the concepts of reflection and refraction.

Table 6.2g: *Extract 3 from the discussion during Activity 2 Exploration and Explanation stages*

Turn No.	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
67 Keith	Reads question from worksheet: Switch on the light bulb and answer the following questions in groups. Where did the colors come from? Why do you think this happened?		
68 Keith	Prism.	SObS/ SObS-EvdL	English

69 Robert	Allura l – **prism** qed tipproduċi dawn il – **colours**. So, the **prism** is producing these **colours**.	SObS/ SObS-EvdL	Code-Switching EvdL and SL
70 Tch	What do you think the prism is doing to the white light?	TchI/ TchI-S	English
71 Noel	The prism reflected the light.	SRQ/ SRQ-SL	English
72 Tch	What do we see when an object reflects light?	TchI/ TchI-E	English
73 Robert	We see that object.	SRQ/ SRQ-EvdL	English
74 Tch	So, if when an object reflects light, we see the object, if a prism reflects light, what are we supposed to see?	TchI/ TchI-S	English
75 Noel	Refracted not reflected, with the r not i	SRQ/ SRQ-SL	English
76 Robert	Mela rridu nduru l – karta u niċċekjaw xi ktibna. We need to go through the handout and check what we wrote.	SLog	Maltese
77 Keith	Nagħmluha fl – aħħar, ok? We do it after we finish this, ok?	SLog	Maltese

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The transcript above shows how the discussion started with Keith and Robert attempting to answer the question in the worksheet. Although Robert's contribution was more detailed than the one provided by Keith and Noel, none of them provided an elaborate enough explanation. Thus, as the teacher, I felt the need to intervene. My aim was to direct the students' thinking about what happens to the beam of light on passing through the prism. In his attempt to answer my question, Noel indicated that he was still experiencing a difficulty in understanding the difference between reflection and refraction and he was using the words interchangeably. To ensure that the students knew this difference, I put forward questions to direct the students to reflect on the two concepts. This enabled me to evidence the students' learning as Robert was able to demonstrate his understanding of the concept of reflection well and Noel was able to demonstrate his understanding of both concepts. During this exchange, the three students contributed to the discussion. The students reverted to speaking entirely in Maltese towards the end of the discussion. This involved Robert suggesting to the group that they should go over their answers in the worksheet to ensure that they had used the correct specialized technical terms of reflection and refraction. Keith also spoke entirely in Maltese to suggest what to do at the end of the investigation. Only Robert code-switched during this exchange and he did so only once at the beginning of the discussion to report directly their observation. In this case, he used English for non-technical terms related to the activity: '*prism*' and '*colours*'. The rest of the contributions were in English, possibly because I posed the questions in English and the students answered in the formal language of assessment, that is, English.

The next step required the students to predict what would happen to the spectrum when a single coloured filter is placed in the path of white light before it enters the prism. Thus, the next step is considered as another exploration stage. The transcript below (Table 6.2h) presents this short exchange.

Table 6.2h: *Extract 4 from the discussion during Activity 2 Exploration and Explanation stages*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
78 Tch	If for example I place a red filter here (pointing to the end of the raybox), which colour/colours might I see?	TchI/ TchI-S	English
79 Robert	The colour of the filter	SRQ/ SRQ-EvdL	English
80 Tch	Can you explain why?	TchI/ TchI-E	English
81 Robert	L – **emergent ray** ikun il – kulur tal – **filter** li nużaw. Il – **filter absorbs** il – kuluri l – oħra. The **emergent ray** will be the colour of the **filter** used. The **filter absorbs** the other colours?	SRQ/ SRQ-SL SAsQ/ SAsQ-SL	Code-Switching SL
82 Keith	I think the filter blocks the other colours.	SRQ/ SRQ-EvdL	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

During this exchange Robert, as he did during previous instances during the engagement stage, replied to my question by sharing his prediction entirely in English. Since he did not provide an explanation for his predication, I asked him to do so. Since Robert is not very proficient in English, he replied by code-switching, using Maltese to explain his reasoning with key expressions in English. Keith, being proficient in English, provided an explanation in English.

After carrying out the investigation, the students had to compare their observations with their prediction about the use of coloured filters. The transcript is presented overleaf (Table 6.2i).

Table 6.2i: *Extract 5 from the discussion during Activity 2 Exploration and Explanation stages*

Turn No.	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
83 Robert	The light was always the colour of the filter.	SObS/ SObS-EvdL	English
84 Keith	When we used different coloured filters, we only saw the colour of the filter closer to the bulb.	SObS/ SObS-EvdL	English
85 Robert	So, the filter blocks the other colours.	SUKE/ SUKE-EvdL	English
86 Noel	Naqbel. I agree.	SAck-Aff	Maltese
87 Keith	So the results proved our hypothesis.	SLog	English

* words written in Blue denote Maltese words

The students did not experience any difficulty in explaining their observations about the use of a coloured filter: the filter blocked the other colours. This was due to the earlier exchange with me (Table 6.2h), where the students predicted that the emergent ray will be the colour of the filter and the filter blocks the other colours. This exchange with me supported their reasoning in Table 6.2i about the effect of a filter when it is placed in the path of white light. This activity, however, was not enough for the students to conclude on their own through direct observation that white light bends several times on passing through a triangular prism and produces a spectrum. Since the syllabus refers only to observation of the phenomenon of refraction and does not require the student to mention that different colours have different wavelength and different refractive index, I did not insist on the students explaining it in terms of different wavelengths and different refractive index. During their exchange, Robert and Keith spoke entirely in English, possibly to respond once again in the language of assessment, that is, in English.

The analysis of this stage shows that out of the 34 conribütions put forward by the students during the exploration and explanation stages, they mainly:

- reported directly what they observed using everyday language (SObS-EvdL – 4 times). *Example: So, the prism is producing these colours*;
- asked questions seeking clarification about contributions put forward by peers (SAsQ-Clr – 4 times). *Example: So, the more we move it away from the light bulb, the more spread out they will be no?*;

- discussed aspects of the task such as what to do and how they carried it out (SLog – 4 times). *Example: We need to go through the handout and check what we wrote*;
- replied to questions using everyday language (SRQ-EvdL – 4 times). *Example: We see that object*;
- replied to questions using scientific language (SRQ-SL – 3 times). *Example: The emergent ray will be the co9lour of the filter used*;
- shared their knowledge to explain using everyday language (SUKE-EvdL – 3 times). *Example: So, the filter blocks the other colours*; and
- shared their knowledge to explain using scientific language (SUKE-SL – 2 times). *Example: Spectrum is a lot of colours*.

The analysis of these stages also shows how the students used different language repertoires depending on the type of conversation taking place. The students spoke mainly by code-switching when sharing their reasoning in Maltese and resorting to English for key expressions in Physics (specialized technical words and non-technical words which are part of the Physics repertoire). The instances when the students spoke only in Maltese was to ensure accuracy in documenting the correct specialized technical terms of reflection and refraction and to express their agreement to their peers' contributions. The students spoke entirely in English in instances where they put forward contributions at the end of the exchange to elaborate on peers' input, when interacting with the teacher and when discussing what to write in their worksheet as their conclusion, to respond to formal questions since school writing in Physics is solely in English.

6.5.4 Activity 2 – Elaboration stage

During the elaboration stage, the activity came to a close, and the students were trying to discuss the observations made and draw conclusions from the data that they gathered.

Table 6.2j: *Activity 2 Elaboration stage - language use*

	Name	English	Maltese	Code-switching	Total
Elaboration stage: Drawing conclusions about how white light behaves when it passes from one medium to another.	Robert	0	0	5	5
	Noel	4	2	0	6
	Keith	2	2	2	6
	Total *4	**6**	**4**	**7**	**17**

Contributions by Noel were dominantly in English. Robert continued to code-switch while Keith used the three different language repertoires equally. The transcript below (Table 6.2k) shows the exchange when the students reflected on their observations to draw conclusions about the use of a filter.

Table 6.2k: *Extract 1 from the discussion during Activity 2 Elaboration stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
88 Noel	Reads question from handout: Based on the results of your investigation, how do you think a filter works? Explain your answer.		
89 Noel	The filters gave different colours to the light.	SObS/ SObS-EvdL	English
90 Tch	What else can you say?	TchI/ TchI-E	English
91 Noel	It changes the colour. No no, it blocks the other colours.	SRQ/ SRQ-ObS	English
92 Keith	The filter allows the colour of it to pass through and it blocks all the other colours.	SElb/ SElb-EvdL	English
93 Robert	Reads question from handout: What do you think would happen if you placed both a red and a blue filter in the path of the white light?		
94 Robert	Dak l – iktar viċin tal – **light bulb** biss naraw. The one closer to the **light bulb** would be seen.	SUKE/ SUKE-Hyp	Code-Switching SL
95 Noel	Ikun aħmar. It would be red.	SUKE/ SUKE-Hyp	Maltese
96 Tch	What would be red?	TchI/ TchI-E	English
97 Noel	The red filter will be close to the light bulb and we will only see the red colour.	SRQ/ SRQ-EvdL SUKE/ SUKE-Hyp	English
98 Tch	Can you explain why?	TchI/ TchI-E	English
99 Robert	L – aħmar **will block** il – kuluri l – oħra, imma mhux l – aħmar, allura aħna ma narawx il – kulur blu, għax il – **blue filter** ikun wara ir – **red filter**. The red one **will block** the other colours, but not red, so we will not see the blue colour, as the **blue filter** will be behind the **red filter**.	SRQ/ SRQ-EvdL SUKE/ SUKE/Hyp	Code-Switching EvdL

100 Tch	Noel and Keith, do you agree?	TchI	English
101 Noel and Keith	Both nod in agreement	SAck-Aff	---------------

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

In the exchange presented in Table 6.2k, the students provided an explanation for their prediction of what happens when a coloured filter is placed in the path of white light between the ray box and the prism. The discussion shows that Noel initiated the discussion by reporting his observation. Thus, I felt the need to intervene to direct the students' thinking that coloured filters block the other colours of the spectrum because the colours are bent several times. Noel and Keith stated that the filter blocked the other colours. When the students were asked to predict what would happen when a red and a blue filter are placed in the path of the light, Robert replied, '*The one closer to the light bulb would be seen'* and Noel added that '*it would be red*'. This shows that the students understood what happens when a single filter is placed in the path of white light between the prism and the sheet of paper but could not articulate their thinking that if two filters are placed, none of the colours would be observed. Thus, I intervened once more to promote thinking. Robert, not being proficient in English, code-switched in his attempt to provide an explanation, which was not elaborate enough since he did not mention that none of the colours would be observed as the blue filter would block the red colour.

During this exchange, Keith and Noel spoke entirely in English when interacting with me as their teacher, and Robert only code-switched. Robert's use of code-switching highlights how this student was more comfortable using Maltese to explain his reasoning but with use of some words in English which are either specialized, technical words or non-technical words related to the activity.

The discussion then moved on to drawing conclusions about white light. The transcript below (Table 6.2l) presents the exchange during the last part of the elaboration stage.

Table 6.2l: *Extract 2 from the discussion during Activity 2 Elaboration stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
102 Keith	Reads question from handout: What can you conclude about white light?		
103 Noel	It can be changed by a prism.	SUKE/	English

		SUKE-EvdL	
104 Robert	Iva, bil – **prism**. Yes, by a **prism**.	SAck-Aff	Code-switching SL
105 Keith	F' **colours** differenti. Into different **colours**.	SElb/ SElb-EvdL	Code-switching EvdL
106 Robert	Li huma **red, orange, yellow, green, blue, indigo** u **violet**. Which are **red, orange, yellow, green, blue, indigo** and **violet**.	SElb/ SElb-EvdL	Code-switching EvdL
107 Keith	Dawn il – colours jissejħu l - i**spectrum of white light**. These are called the **spectrum of white light.**	SElb/ SElb-SL	Code-switching SL
108 Tch	Can you elaborate a bit more? Remember that you used the word refraction before.	TchI/ TchI-E	English
109 Keith	A prism refracts white light into colours (those colours) and produces the spectrum of white light.	SRQ/ SRQ-SL	English
110 Keith	Naf li hemm kelma partikolari għaliha, imma ma nistax niftakarha issa. I know that there is a particular word for it, but I can't remember it now.	No MCode	Maltese
111 Robert	Forsi nistgħu nżiedu li **when white light enters a prism, the beam of light is refracted, and it produces the colours** u niktbuhom and nispiċċaw b'dak li qal Keith? Maybe we can add that **when white light enters a prism, the beam of light is refracted, and it produces the colours** and we write them and then finish off with what Keith said?	SElb/ SElb-SL	Code-Switching EvdL and SL
112 Noel	Iva naqbel. Yes, I agree.	SAck-Aff	Maltese
113 Keith	Anki jien. Me too	SAck-Aff	Maltese-

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The discussion first focused on how white light '*can be changed by a prism*' into seven colours, with Keith stating the scientific name of these colours, '*spectrum*'. These social exchanges demonstrate the students' ability to report correctly their observation in detail. Noel, being proficient in English, responded to the question in the worksheet entirely in English. Robert continued to code-switch, and Keith also code-switched while interacting with Robert. In this exchange, the only contribution entirely in English by Keith was to reply to my question. Since the students did not articulate their observations in terms of physics concepts, I intervened to scaffold their thinking by making direct reference to the concept of refraction, which had already been covered and discussed during the engagement stage of this IBL activity. Keith then switched to speaking entirely in Maltese to indicate that he was familiar with the phenomenon of dispersion of white light '*I know that there is a particular word for it but can't remember it now*' as he struggled to find the right technical word in English. Robert and Noel did not enquire about Keith's reference to the particular term for this phenomenon, and Keith did not push it further. In fact, Robert just put forward his suggestion of what the group should add to write a detailed conclusion about white light. Here Robert continued to code-switch, using English for key scientific expressions. As in previous exchanges, Keith and Noel used entirely Maltese to express their agreement to their peer's contribution, in this case, to Robert's suggestion of what to write as their conclusion.

The analysis of this stage shows that during the elaboration stage, out of the 17 contributions put forward by the students, they mainly:

- acknowledged by affirming contributions put forward by peers (SAck-Aff – 4 times). *Example: Yes, by a prism*;
- shared their knowledge to hypothesise (SUKE-Hyp – 4 times). *Example: It would be red*;
- elaborated on previously shared ideas by using everyday language (SElb-EvdL – 3 times). *Example: Which are red, orange, yellowm green, blue, indigo and violet*;
- elaborated on previously shared ideas by using scientific language (SElb-SL – 2 times). *Example: …we can add that when white light enters a prism, the beam of light is refracted, and it produces the colours*; and
- replied to questions using everyday language (SRQ-EvdL – 2 times). *Example: The red one will block the other colours, but not red, so we will not see the blue colour, as the blue filter will be behind the red filter*.

On analysing this experience, I concluded that:

- ***Presenting a structured IBL activity engaged the students more:*** This IBL activity was straightforward as a structured IBL activity as it provided the students with the key inquiry question and the steps needed to follow during the investigation. These made it easier for the students to understand what they had to do and what they needed to investigate. The students were also evidently getting accustomed to the IBL approach. They were thus more engaged when carrying out the investigation. They were becoming accustomed to talking and discussing as they work.

- ***The students understood the concepts of reflection and refraction, and also understood the concept of dispersion of white light:*** The aim of this activity was to implement an IBL activity which enabled the students to understand that white light is refracted when it passes from one medium to another and a spectrum is produced. The students managed to explain fully their observations during the investigation. This meant that the students achieved a good level of understanding as I had planned.

- ***There was more talk during the activity:*** I can consider that there was a significant improvement in the degree of talk taking place during the activity, both during the investigation, as well as during the plenary. The quality of the talk also moved from only describing their observations to trying to explain what was happening.

- ***The students' language preference appears to influence their choice of language to use:*** Robert preferred Maltese and code-switched when referring to physics aspects. Noel tended to speak in English when talking physics and suggesting what to write in response to the questions in the worksheet but resorted to Maltese and code-switching when interacting directly with Robert. He also spoke entirely in Maltese when the conversation was less scientific and thus, no technical words were needed. This also applied to Keith, who also spoke either in English or code-switched when talking physics. He code-switched mainly when interacting directly with Robert. Moreover, it was noted that the students responded in English directly after I asked a question. This showed that while there was an increase in talk, the first language Maltese speakers reflected their language proficiency.

Collating my reflections and evaluation using Kolb's cycle, Table 6.2m overleaf presents a summary of my experience of the second activity carried out, my reflections on the outcomes of the IBL activity, the hypotheses that emerged from the analysis, and my plan for the third activity in this cycle.

Table 6.2m: *Research design following Kolb's cycle of reflection – Cycle 2 Activity 2*

Stage 1: Experience	From the second IBL activity during this cycle, I noticed that presenting the students with a structured IBL and having more freedom in language use, enabled them to engage in more discourse. I can consider that there was an improvement in the degree of talk taking place. I also noted that their language preference appeared to influence their choice of language to use. They were also able to use scientific terminology – reflection, refraction and spectrum – well in their responses.
Stage 2: Reflections	This structured IBL activity showed that the students were becoming more accustomed to IBL. The students were able to demonstrate their learning. They started slowly to move away from just noting observations to also attempting to present explanations, using correct technical terminology. Allowing the students to express themselves in their preferred language allowed more discussion and social construction of knowledge to take place.
Stage 3: Generalisations/ Hypotheses	The more students experience IBL activities and are afforded opportunities to use their preferred language, the more they learn to talk and engage in social construction of knowledge. They will learn physics concepts better as well as learn how to express themselves in correct scientific way.
Stage 4: Plan	I thus planned to implement a guided/open inquiry-based learning activity as the students had gained experience with structured and guided IBL. I wanted to go a step further and give them space to contribute to the design of the investigation - making the activity more open. I also wanted to focus more on how aware the students were in the need to learn how to express themselves well in English for assessment purposes.

The reflections and evaluations of this activity fed into the methodology for the third activity of this cycle. With the above research design in mind, the third IBL activity of this cycle was planned.

6.6 Design and Implementation of the third activity of Cycle Two: Egg drop – land it safely

Based on my reflections on Activity 2, I planned another IBL activity, this time on the topic of Forces. The students were presented with an inquiry challenge related to Newton's Second Law of motion by focusing on collisions and the effect that the time of impact has on the resulting force of impact on the colliding objects (impulse). The context considered was that of dropping eggs. The activity was introduced by watching a video (https://www.youtube.com/watch?v=8b-Mogqy1h4) about racing cars, car crashes and the use of crumple zones. The video demonstrated the effect of a car collision on a dummy in different types of crashes; one when the impact time (the time taken to bring the force acting on the car and the dummy to a stop) was short (without a seatbelt) and when the impact time was increased (with a seatbelt which extends). The aim of this video was to get the students thinking about the duration (time of impact) of the collision, and its effect on the force of impact which results. This activity was carried out over two double lessons, a total of 160 minutes. This was required because it allowed enough time for the task to be completed. It was a guided/open inquiry and not structured because in this case, the students were invited to design the investigation themselves, using the materials provided.

This inquiry-based learning activity was designed in the following 5E stages:

- ***Engagement:*** I introduced the investigation myself by showing the students a video about car collisons. The students were then invited to reflect on the relation between the time taken for the colliding bodies to come to a stop and the force of impact. The students also had to reflect in groups on the factors that would affect an egg breaking when dropped. It was expected that the students here would mention "speed" and "height" as factors. The students were not expected to mention time as one of the factors, as it could not be observed or measured.
- ***Exploration:*** The students had to test their ideas about which factors determine whether an egg will break when dropped on different surfaces. The students were not given any cues or help about which factors they had to keep constant or not, or how to design and carry out the investigation. The students were provided with a dozen eggs, flour, sand, a metre rule, measuring tape and 3 bowls. A worksheet was used which is provided in Appendix 12.
- ***Explanation:*** The students had to explain that the longer the time of impact to bring the bodies to a stop, the less the force of impact would be. Since the students were already familiar with the physics concepts behind the context they were engaging with, it was expected that they would refer to speed, acceleration, momentum and force of impact. The students were not specifically asked to refer to or use their previously acquired knowledge about the above-mentioned physics concepts. This was purposely done to see how the discussion would proceed, i.e. whether the students would spontaneously use the physics concepts already learned or not.
- ***Elaboration:*** The students had to discuss how the egg could be protected from breaking when landing by using their conclusions about the

relationship between time and the force of impact. They also had to test their way of protecting the egg;

- ***Evaluation:*** The students' answers to the questions set in the worksheet, as well as their presentations enabled me to evaluate how the students understood the relationship between the time factor and the force of impact when two bodies collide and whether their experience in engaging in IBL activities was enough to move to less structured IBL activities in a bilingual setting.

This part of the Physics curriculum focuses on the concept of impulse. According to Newtons Second Law, the force (F) on an object is directly proportional to the object's acceleration (a). $F \propto a$, leads to the equation $F = ma$ where by definition, $a = (v – u)/t$ where v stands for final velocity, u stands for initial velocity and t stands for time. The equation for impulse (Ft) is $Ft = mv – mu$. It can thus be inferred from this equation that for a collision where change in momentum (mv – mu) is constant, the force of impact is indirectly proportional to the time of impact ($F \propto 1/t$). This leads to the physical explanation of why longer time of impact leads to smaller force of impact. The Physics syllabus at secondary level does not expect the manipulation of the equation $F = ma$, nor does it mention impulse directly. It only expects a qualitative understanding of this concept and its application of practical examples. This is why a practical activity was planned and implemented.

During this IBL activity the students engaged with a context related to collisions, starting from cars colliding and moving on to dropping an egg. The physics concepts of momentum and impulse had already been tackled during previous lessons. Thus, the students were already familiar with Newton's First Law – that if a body is at rest or moving at a constant speed in a straight line, it will remain at rest or keep moving in a straight line at constant speed unless it is acted upon by a resultant force. They were also familiar with momentum, which depends on the mass and the velocity; free fall and Newton's first and second laws of motion.

6.6.1 Analysis of Activity 3: Egg Drop: Make it land safely

6.6.2 Activity 3 – Engagement stage

There were two parts in this stage. The first part was to introduce the students to the relation betweent the force of impact and time of impact and the second part required the students to predict what factors influence whether an egg will break when dropped through a height. There were very few contributions put forward by the students who participated in this action research study (just 7). This was probably due to the session involving a context that the students were not familiar with and the theme was also being introduced. It was only two students from the target group (Robert and Yuri), who contributed in this discussion. This is similar to what happened in Activity 1. This highlights how the students tend to speak less when the discussion is teacher led. Moreover, in this case, the discussion also involved a context they were unfamiliar with: the use of crumple zones, so the best they could do at this stage was speculate about the effect of crumple zones.

Table 6.3a: *Activity 3 Engagement stage – language use*

	Name	**English**	**Maltese**	**Code-switching**	**Total**
Engagement stage: Introducing the relation between the time taken for the colliding bodies to come to a stop and the force of impact by watching a video about car collisions.	Robert	1	2	3	6
	Noel	0	0	0	0
	Matthew	1	1	0	2
	Keith	0	0	0	0
	Yuri	10	0	0	10
	TOTAL *1	**12**	**3**	**3**	**18**

It is noted that Yuri spoke entirely in English while Robert used the three different language repertoires, he mainly code-switched or spoke entirely in Maltese. This highlights how the students feel comfortable participating in the discussion using their preferred language. The transcript overleaf (Table 6.3b) provides insight into what the students were reflecting on and how Robert changed his language repertoires. Though KerryAnn and Reem were active participants during the discussion at this stage, their contributions were not taken into consideration in table 6.3a as both students were not part of the participating group. The participating group consisted of Robert, Noel, Matthew, Keith and Yuri.

__Table 6.3b:__ Extract 1 from the discussion during Activity 3 Engagement stage

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
1 Tch	What did you understand?	TchI/ TchI-E	English
2 Yuri	Cars are designed with a crumple zone.	SRQ/ SRQ-SL	English
3 Tch	What can you say about the crumple zone?	TchI/ TchI-E	English
4 Yuri	It absorbs the impact energy, so it decreases the force.	SUKE/ SUKE-SL	English
5 Tch	What about you? (addressing the whole class)	TchI/ TchI-E	English
6 KerryAnn	Is this why old cars don't get so much damaged when they crash?	SAsQ/ SAsQ-EvdL	English
7 Robert	Yes, cause the body was not designed with a crumple zone.	SUKE/ SUKE-SL	English
8 KerryAnn	So older cars are better?	SAsQ/ SAsQ-EvdL	English
9 Tch	In what ways do you think that they are better?	TchI/ TchI-E	English
10 KerryAnn	They didn't get badly damaged, so they didn't need to pay a lot of money to fix the cars.		English
11 Yuri	They paid a higher price though!		English
12 Reem	Why?	SAsQ/ SAsQ-Clr	English
13 Robert	In – nies isofru aktar. People suffer more.	SUKE/ SUKE-EvdL	Maltese
14 Yuri	Cause when a car squashes, there will be less impact energy on the person.	SUKE/ SUKE-SL	English
15 Reem	Oh, it makes sense.	SAck-Aff	English
16 Robert	Illum il – ġurnata l – karozzi jispiċċaw diżastru biex jipprotteġu lilek. Huma magħmula b'tali mod li l – karozza ġġarrab ħafna ħsara u int iġġarrab inqas. Nowadays cars end up in a mess for your own safety. They are designed in a way that the car gets a lot of damage and you suffer less.	SUKE/ SUKE-EvdL	Maltese
17 Tch	I like the way you described the reason behind the use of crumple zones. So, I am going to give you a handout each. First, we are going to concentrate on Part A. We have some instructions written down. So, I am going to give you a handout each. First, we are going to concentrate on Part A. We have some instructions written down.	TchI	English

* words written in Blue denote Maltese words

The transcript above shows that the discussion started with Yuri attempting to make sense of his understanding of crumple zones. In his attempt he did not articulate the physics content well, as crumple zones are designed to prolong the contact time between the colliding bodies and thus decrease the force of the impact on the occupant. This was expected. Despite this, his contribution still shows that he was trying to make sense between what they had watched in the video and what they had previously learnt. He knew that crumple zones had an impact on the force of collision, but he thought that they absorbed energy. Here he was probably referring to kinetic energy due to movement. However, he could not articulate how the absorption of [kinetic] energy led to a smaller force of impact. My intention here was for the students to realise that in a collision where change in momentum ($mv - mu$) is constant, the force of impact is indirectly proportional to the time of impact ($F \propto 1/t$), which leads to the physical explanation of why longer time of impact leads to smaller force of impact. The discussion then moved on to reflecting on whether older cars are better. The students' thinking shifted from, assuming that older cars are better as they experience less damage when involved in a car crash, to understanding that the use of crumple zones causes a lot of damage to the vehicle to decrease injuries on the driver/passengers. This reflects that the students did relate crumple zones to less damage to the driver but could not articulate it in terms of physics concepts. In fact, they did not make any reference to time, which is what this activity was targeting. This is understandable as time could not be observed or measured due to very small differences, making it less evident for the students to notice. Any attempts at explanation referred to energy, which shows that the students were not applying Newton's Laws of motion to this context. This means that although their attempts to explain the use of crumple zones referred to energy, which were valid, these explanations were not what I intended them to speculate upon.

The students made more contributions in the second part of this stage compared to the first part. Here they were asked to predict what factors influence whether an egg will break when dropped through a height. As in the case of Activity 1, this highlights how the nature of the task, which asked the students to propose which factors affect an egg breaking when dropped, engaged the students in more exchanges as they had to present their ideas about the practical context.

It is noted that during this part of the engagement stage, Noel and Keith did not put forward any contributions, while Yuri and Robert dominated the discussion. It is also noted how these students used their preferred language: Yuri spoke in English and Robert code-switched. Matthew spoke once entirely in Maltese and once entirely in English. Considering the transcripts overleaf (Tables 6.3c – 6.3e) provides more insight into what the students were reflecting on and how they used different language repertoires. Utterances 18-25 were off-task, that is, when the students discussed something that had nothing to do with the topic/task (Hogan, Nastasi and Pressley, 1999), while the students were settling down to work in groups. Thus, these utterances were not taken into consideration.

Table 6.3c: *Extract 2 from the discussion during Activity 3 Engagement stage*

Turn No.	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
26 Yuri	The egg will break, depending on the material it lands on.	SUKE/ SUKE-Hyp	English
27 Robert	U t – **texture**. And the **texture**.	SUKE/ SUKE-Hyp	Code-Switching EvdL
28 Yuri	How it will land as well.	SUKE/ SUKE-Hyp	English
29 Matthew	X'inridu niktbu allura? What do we have to write though?	SAsQ/ SAsQ-Log	Maltese
30 Reem	Jien smajt dak li kontu qed tgħidu u naqbel, ghax int ma tistax tkisser bajda hekk, imma hekk biss. I overheard what you were saying, and I agree, because you cannot break an egg like this, but only like this. (student added gestures: holding something horizontally as well as vertically)	SElb/ SElb-EvdL	Maltese

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The discussion was started off as I read the question: '*What factors make it possible for the egg to land safely? Identify the factors, which determine whether an egg breaks when dropped*.' This question was then repeated in Maltese, but no explanation or guidance was provided to the students. The exchange above shows that Yuri considered the material the egg lands on as well as the orientation of how the egg is dropped as possible factors. However, he did not specify how this would affect the egg when landing horizontally or vertically as factors which affect an egg breaking when dropped. Robert also referred indirectly to the material the egg lands on, by referring to the texture of the material.

The students were expected to make connections between the knowledge that they had acquired in the previous lessons (concept of momentum, force of impact and Newton's First and Second Laws of motion) and their observations together with the knowledge they acquired from the initial part of this IBL activity (video and whole class discussion about the mechanisms of safety equipment in vehicles – crumple zones) to identify factors, which determine whether an egg breaks when dropped. Furthermore, the students had not yet, at this point, made any reference to time of impact, which varies according to the type of material the egg lands on. This is understandable as time could not be observed or measured due to very small differences, making it less evident for the students to notice, even though I had expected that the video watched while introducing the activity could have possibly directed their thinking to the time factor. Since the time of impact was a factor which this investigation was targeting, I felt the need to intervene to direct the learners' thinking towards considering other factors than the ones they mentioned. The discussion which followed my intervention is presented in the transcript below.

Table 6.3d: *Extract 3 from the discussion during Activity 3 Engagement stage*

Turn No.	**Utterance**	**IBL Main Code & Sub-Code**	**Language Use**
31 Tch	So, what do you think are the factors that will affect the egg?	Tchl/ Tchl-S	English
32 Reem	Speed.	SRQ/ SRQ-SL	English
33 Robert	L – **orientation** ta kif twaddab il – bajda. The **orientation** of how you drop the egg.	SElb/ SElb-EvdL	Code-switching EvdL
34 Reem	Yes, cause if it lands horizontally there is a bigger chance for the egg to break.	SElb/ SElb-EvdL	English
35 Yuri	Height and material, it lands on.	SUKE/ SUKE-EvdL	English
36 Robert	Mela waqt l – **experiment,** l – **orientation** trid tibqa l – istess. So, during the **experiment**, the **orientation** has to be the same.	SLog	Code-switching EvdL
37 Yuri	Even the height has to be constant.	SLog	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The exchange above (Table 6.3d) shows that the group identified three factors which affect the egg breaking when dropped: '*orientation*', '*height*' and the '*material*' that it lands on. Reem, who was not part of the participating group, also identified '*speed*'. However, they did not provide an explanation using physics concepts on the role that the factors they identified have on the situation/example being considered. While identifying these factors, the students also pointed out that both the orientation as well as the height from which the egg is dropped need to be constant during the investigation. The students' awareness of the need to control other variables when carrying out the investigation focusing on one variable, reflects their knowledge of fair testing.

Since the students were focusing mainly on the methods of their investigations, I felt the need to intervene once more. This time, to invite the students to explain why they had suggested that the height and the orientation needed to be kept constant (Table 6.3e below).

Table 6.3e: *Extract 4 from the discussion during Activity 3 Engagement stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
38 Tch	Can you explain to me why you have decided to keep both the height and the orientation constant?	TchI/ TchI-E	English
39 Yuri	So, so we can focus only on the material. We will be changing the height for every drop for every material, until it breaks when landing on one or not but not on the three of them.	SRQ/ SRQ-EvdL	English
40 Matthew	It also depends on the density of the material. It might not sink in flour because flour is denser than the egg.	SUKE/ SUKE-SL	English
41 Yuri	But we cannot find the density of flour or sand or the beach. I don't think we should get into that. (referring to density).	SReb/ SReb-PSK	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The short exchange above shows how my role was a catalyst to eliciting a clear explanation of the methodology needed for a fair test, where only one factor needs to be changed and the rest kept constant. This was evidenced by Yuri's answer. It also enabled Matthew, to identify another possible relevant variable, the density of the landing material. From the context of the rest of the exchange, it can be inferred that Matthew held an understanding of comparative densities. Matthew's contribution was, however, rebutted by Yuri, and Matthew gave in to that. At this point, I as their teacher felt that the students needed to be directed to plan an investigation to test their predictions.

The analysis of the engagement stage shows that out of the 18 contributions put forward by the students, they mainly:

- shared their knowledge to explain using everyday language (SUKE-EvdL – 4 times). *Example: Height and material, it lands on*;
- shared their knowledge to hypothesise (SUKE-Hyp – 3 times). *Example: The egg will break, depending on the material it lands on*;
- shared their knowledge to explain using scientific language (SUKE-SL – 2 times). *Example: It absorbs the impact energy, so it decreases the force*; and
- discussed aspects of the task such as what to do and how to carry out the investigation (Slog – 2 times). *Example: So, during the experiment, the orientation has to be the same.*

The analysis of this stage also highlights how the students use their preferred language to explain their reasoning (foreign student talking in English and the first-language Maltese speakers talking in Maltese). Robert used the English language once, when I, as their teacher was an active participant in the discussion. A possible reason why he used the English language could be that he was referring to what he had observed and listened to in the video '*the body was designed with a crumple zone'*. However, when Robert was referring to experiences from outside the classroom (Turn 16 in Table 6.3b), he spoke only in Maltese. This is another example of how Robert uses his native language (Maltese) when speaking about everyday experiences but tries to speak in English when talking formal Physics, as discussed in section 6.4.3 when he referred to how tired he gets when running up a flight of stairs for hundred times and in section 6.5.3 when he compared the effect of the distance between the sheet of paper and the prism on the brightness of the colours produced, to a beam of light produced by a flashlight to see objects at a distance. Similar to previous instances, when Robert code-switched, he used Maltese to share his reasoning but resorted to using English for non-technical words related to the activity. Examples of such English words included "texture", "orientation" and "experiment" which are words used commonly in everyday language where laymen code-switch when they speak, even though words in Maltese exist for "orientation" and "experiment". Matthew spoke once in Maltese and once in

English. He used exclusively Maltese to ask for instructions related to what they had to write but used English exclusively when the teacher was an active participant in the discussion, as he was interacting directly with Yuri. This shows how this student tried to speak in English in those instances which he considered as formal Physics exchanges. This was not consistent throughout Cycle Two. In fact, it was observed that only during this activity, Matthew tried to speak in English in such instances, as during the first activity of this cycle, he spoke in Maltese and resorted to English for specialized technical terms.

6.6.3 Activity 3 – Exploration stage

In this stage of the activity, the students were involved in implementing the investigation to test the factors that they had identified.

Table 6.3f: *Activity 3 Exploration stage – language use*

	Name	English	Maltese	Code-switching	Total
Exploration stage: Carrying out the investigation to test the factors identified in the engagement stage.	Robert	1	1	3	5
	Noel	2	0	0	2
	Matthew	0	1	0	1
	Keith	0	0	0	0
	Yuri	3	0	0	3
	Total *3	**6**	**2**	**3**	**11**

All the participants except Keith contributed to the discussion in this stage of the activity. Similar to previous exchanges, Yuri spoke entirely in English while Robert continued to code-switch. Noel spoke predominantly in English. Matthew only put forward one contribution during this stage, and he did so entirely in Maltese. This highlights how the students feel comfortable participating in the discussion using different preferred languages. The transcript overleaf (Table 6.3g) shows how in this stage, the students negotiated how to take the measurements that they needed for the investigation. The conversation focused on ensuring systematic measuring and ensuring accuracy, which are important process skills when carrying out experiments and investigations in Physics.

Table 6.3g: *Extract from the discussion during Activity 3 Exploration stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
44 Yuri	Flour is lighter, softer, so if we drop it from the same height and the same speed, there is a bigger chance that it will not break on flour.	SUKE/ SUKE-Hyp	English
45 Tch	Have you considered a different surface, maybe a harder one or a softer one?	TchI/ TchI-S	English
46 Robert	Ikun ok jekk inwaddbuha fl – art u fuq il – bank? Is it ok if we drop it on the floor or on the bench?	SAsQ/ SAsQ-Log	Maltese
47 Tch	Iva. Yes.	TchI/ TchI-R	Maltese
48 Robert	Mela, rridu nżommu l – **height constant** u nwaddbu l – bajda fuq il – bank, id – dqiq u r – ramel u naraw x'jiġri. So, we keep the **height constant** and drop the egg on the bench, flour and sand and we see what happens.	SLog	Code-switching EvdL
49 Matthew	Żgur tinkiser fuq il – bank, iebes ħafna. It will surely break on the bench, too hard.	SUKE/ SUKE-EvdL	Maltese
50 Robert	Irridu nżommu l – **orientation constant** ukoll. We also need to keep the **orientation constant**.	SLog	Code-switching SL
51 Noel	Let me hold the ruler. Robert, you drop the egg. Don't throw it, just drop it so speed won't change.	SLog	English
52 Yuri	Let's try from the 30cm mark.	SLog	English
53 Robert	Ok. Taqblu li qeda fuq it – **30cm mark**? Ma nistax nara sew minn hawn fuq. Ok. Do you agree that it is on the **30cm mark**? I can't see properly from up here.	SAsQ/ SAsQ-Log	Code-switching EvdL
54 Noel	Yes. (Yuri nods)	SAck-Aff	English
55 Yuri	Remember to always drop it like this.	SLog	English
56 Robert	OK (giggles)	SAck-Aff	----------------
	Egg was dropped on sand and flour.		
57 Yuri	Come on. Try it on the bench now. (giggles).	Slog	English
	The egg broke when dropped on the bench.		
58 Robert	We don't need to try it from a higher height on the bench, as it will surely break.	SLog	English

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The extract above shows how the discussion started with Yuri who predicted that when the egg is dropped on different surfaces and the height is kept small and is kept constant, it might not break on flour. He did not provide an explanation of why this is so in terms of crumple zones. Here I intervened to guide the students to focus on the type of material as the independent variable, which enabled Robert to reflect and put forward another prediction – that the floor and the bench are hard surfaces and will thus crack the egg. The discussion then moved on to the students demonstrating their understanding of controlling variables. When they dropped the egg from a height of 30cm, it broke when it fell on the bench and sand, but not when it fell on the flour. Robert concluded that his prediction was correct and stated that there was no need to test the effect on the egg when dropping it on the bench from heights greater than 30cm. Since at this stage, the students reported directly their observations but did not articulate what they had observed in terms of physics concepts already learnt (speed, acceleration, momentum and force of impact), I felt the need to intervene. The possibility that the students might have needed more time to articulate what they had observed was not taken into consideration. Since my intervention aimed at inviting explanations, the transcript of this exchange is presented in section 6.6.4, which tackles the explanation stage of the 5E's model.

The analysis of the exploration stage shows that out of the 11 contributions put forward by the students, they mainly:

- discussed aspects of the task such as what to do and how they carried it out (Slog – 5 times). *Example: So, we keep the height constant and drop the egg on the bench, flour and sand and we see what happens*;
- asked questions seeking logistical responses (SAsQ-Log – 2 times). *Example: Do you agree that it is on the 30cm mark? I can't see properly from up here*; and
- acknowledged by affirming contributions put forward by peers (SAck-Aff – 2 times). *Example: Yes*.

The analysis of the exploration stage also shows similar language use patterns observed in the other two IBL activities of this cycle: the English language was mainly used by Yuri, which was as expected, while Robert mainly code-switched. The majority of the contributions were put forward by Robert. He mainly code-switched while discussing ways to carry out the investigation and ensuring accuracy when carrying out the investigation. Similar to previous exchanges, when he code-switched, he used the Maltese language to share his reasoning but integrated English everyday words which were integral to the activity. He thus used words such as: "30 cm mark", "height", "orientation" and "constant" in English. During this stage, on the other hand, Noel spoke entirely in English.

Although he was not interacting directly with Yuri, Noel possibly spoke only in English at this instance as he considered Yuri as English speaking.

6.6.4 Activity 3 – Explanation stage

During this stage, the students had to explain that the longer the time of impact to bring the bodies to a stop, the less the force of impact would be.

***Table 6.3h:** Activity 3 Explanation stage – language use*

	Name	English	Maltese	Code-switching	Total
Explanation stage: The students had to explain that the longer the time of impact to bring the bodies to a stop, the less the force of impact would be.	Robert	0	0	3	3
	Noel	1	1	0	2
	Matthew	0	0	0	0
	Keith	0	2	1	3
	Yuri	0	0	0	0
	Total *3	**1**	**3**	**4**	**8**

During the explanation stage (Table 6.3i), I was an active participant in the discussion. Yuri was not present as he was called to the clerks' office. It is noted that in Yuri's absence, there was no use of English by the first-language Maltese speakers. In fact, the only significant contribution from Noel was in Maltese as his contribution in English was just 'Yes'. Keith and Robert also contributed to the discussion.

***Table 6.3i:** Extract from the discussion during Activity 3 Explanation stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
59 Tch	Have you discussed 1.2? (the question in the handout)	Tchl	English
60 Noel	Yes.	No Main Code	English
61 Tch	What have you come up with?	Tchl/ Tchl-E	English
62 Noel	Meta l – bajda waqgħet minn distanza qasira, inkisret biss fuq il – mejda, pero meta żidna d – distanza, inkisret fuq ir – ramel imma ma nkisritx fid – dqiq. When the egg was dropped from a short distance, it only broke on the table, while when we increased the distance, it broke on sand but it didn't break on flour.	SRQ/ SRQ-ObS	Maltese
63 Tch	What can you say about this? Can you explain why this happened?	Tchl/ Tchl-E	English

64 Keith	Ħabba li d – dqiq huwa **soft**, il – bajda baqgħet nieżla, qisu mewwet l – **impact**. Since the flour is **soft**, the egg sank, and so it kind of killed (decreased) the **impact**.	SRQ/ SRQ-SL	Code-switching EvdL and SL
65 Robert	Id – dqiq qisu kein il – **crumple zone**. The flour acted like the **crumple zone**.	SElb/ SElb-SL	Code-switching SL
66 Tch	Tista' tispjega ftit aktar fid – dettal? Can you explain it a bit more in detail?	TchI/ TchI-E	Maltese
67 Robert	Id – dqiq tferrex u l – bajda baqgħet nieżla aktar l – isfel fil – bowl, it **– time of hitting**, jew **contact** bejn il – bajda u d – dqiq żdied, allura l – **energy**, mmm **speed**, naqas bil – mod. The flour spread and so the egg went further down in the bowl, increasing the **time of hitting**, or **contact** of the egg and the flour, so **energy** mmm **speed** decreased slowly.	SRQ/ SRQ-SL	Code-switching
68 Keith	Jien naħseb li kieku użajna bowl aktar fonda, l – bajda ma kienitx tinkiser fuq ir – ramel. I think that if we had used a deeper bowl, the egg wouldn't have broken on sand.	SUKE/ SUKE-Hyp	Maltese
69 Robert	Qisu tkun tilfet l – i**speed** u titnaqqas is – saħħa tal – **impact**. Kind of it would have lost the **speed** and decreased the strength of the **impact**.	SElb/ SElb-SL	Code-switching SL
70 Keith	Eżatt. Exactly.	SAck-Aff	Maltese
71 Tch	Nodded.	SAck-Aff	

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The exchange above shows that Noel reported directly their observations with accuracy and detail. Here Noel identified a relationship between height and whether the egg breaks. Moreover, when the students were asked to explain their observations, at first, they only managed to describe their observations. One possible reason why the students did not provide an explanation why the egg broke could be that the students were not used to providing explanations for their observations but trained more in recording their observations. The students were able to link contact time with force of impact and applied a physics concept learnt in one context (cars) to another (egg) after my intervention. I can note that my role was a catalyst in promoting reflections by purposely posing the following questions: '*What can you say about this? Can you explain why this happened?' and 'Can you explain it a bit more in detail?*'. These questions enabled the students to apply what they had learnt about crumple zones for cars to the egg (landing on soft material decreased the force of impact; the effect of landing on sand was linked with crumple zones).

Noel was able to report their observations of the investigation with great detail in Maltese. Keith contributed twice: once in entirely Maltese and once by code-switching. Keith used Maltese to explain his reasoning but reverted to English for key expressions such as “impact” and for non-technical words related to the activity, such as “soft”. Robert continued to code-switch and similar to other previous exchanges, when he code-switched, he used the Maltese language to share his reasoning and understanding and used English for words which are part of the Physics repertoire, such as “crumple zone”, “time of hitting”, “contact”, “energy”, “speed” and “impact”.

The analysis of the explanation stage shows that out of the 8 contributions the students put forward in their attempt to explain their observations and the data they collected, they used scientific language mainly when they:

- replied to questions using scientific language (SRQ-SL). *Example: Since the flour is soft, the egg sank, and so it kind of killed (decreased) the impact*; and
- elaborated on previously shared ideas by using scientific language (SElb-SL). *Example: Kind of it would have lost the speed and decreased the strength of the impact*.

The analysis of this stage also highlights how first-language Maltese speakers did not speak entirely in English when Yuri was not present, but they either spoke entirely in Maltese or code-switched. This is similar to the language repertoires used in Activity 2 (Table 6.2b), when Yuri was absent. It is also noted that even when the teacher was an active participant in the discussion, these students either spoke in Maltese or by code-switching, as opposed to the language repertoires the students used in Activity 2. One possibility why the students used their preferred language repertoires even when interacting with the teacher could be that they were becoming used to using their preferred language not only when engaging in dialogue among themselves, but also when engaging in the dialogue with the teacher. Similar to previous exchanges, when the students code-switched, they shared their reasoning in Maltese but used English for key expressions and non-technical words related to the activity.

6.6.5 Activity 3 – Elaboration stage

This elaboration stage represents the closing part of the activity. The students were asked how they could protect the egg to ensure that it does not break. The students made many contributions during this phase. This highlights how the task managed to engage the students. This phase invited them to present their ideas on reflecting about the practical context of ways through which they could protect an egg when dropped. In this activity the students were expected to draw conclusions about the relationship between time of impact and the force of impact which results when the egg lands on different surfaces.

Table 6.3j: *Activity 3 Elaboration stage – language use*

	Name	English	Maltese	Code-switching	Total
Elaboration stage: Discussing and investigating how the egg could be protected when dropped by using their conclusions about the relationship between time and the force of impact.	Robert	1	0	5	6
	Noel	0	7	3	10
	Matthew	4	5	3	12
	Keith	0	1	5	6
	Yuri	1	0	0	1
	Total *4	**6**	**13**	**16**	**34**

It is noted that during this stage, there was preference for code-switching, followed by use of Maltese. The table above shows how Noel and Matthew made most contributions towards the discussion. It is also noted that Robert and Matthew made some contributions entirely in English. Moreover, it was only Matthew who made use of the three different language repertoires during this stage. It is important to note that Yuri, only returned to the class towards the end of this stage. This is possibly the reason for more use of Maltese and code-switching by the first language Maltese speakers during the discussion. Considering the transcripts overleaf (Tables 6.3k – 6.3m) provide more insight into what the students were reflecting on and how they used different language repertoires. Table 6.3k presents the students' exchanges while they were putting forward their ideas of how to protect the egg from breaking.

Table 6.3k: *Extract 1 from the discussion during Activity 3 Elaboration stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
72 Noel	X'materjal ħa nużghu għat – tieni parti? What kind of materials are we going to use for part two?	SAsQ/ SAsQ-Log	Maltese
73 Robert	Aħna rridu nipproteġu l – bajda meta tinżel fuq **hard surfaces**, le? We need to protect the egg when it lands on **hard surfaces**, no?	SAsQ/ SAsQ-Clr	Code-switching EvdL
74 Matthew	Yes. Bubble wrap or kite paper.	SLog	English
75 Robert	Anki jekk ingeżwruha f' **tissues**. Even if we wrap in **tissues**.	SLog	Code-switching EvdL
76 Matthew	Nistgħu nipproteġuha wkoll billi ndawru l – **cotton** magħha. We can also protect it by wrapping **cotton** around it.	SLog	Code-switching EvdL
77 Keith	Nistgħu wkoll innaqsu l – **height** u nwaddbuha **horizontally**. We can also decrease the **height** and drop it **horizontally**.	SLog	Code-switching SL
78 Matthew	Ma nistgħux inwaddbuha fid – dqiq la ma nkisritx? Can't we just drop it in flour since it didn't break?	SAsQ/ SAsQ-Log	Maltese
79 Noel	Le, għax irridu nużgħu **bowl** vojta. Irridu naħsbu f'xi ħaġa biex nipproteġuha meta tillandja fuq **tray** vojt. No, because we need to use an empty **bowl**. We have to think of how we can protect it when it lands on an empty **tray**.	SRQ/ SRQ-EvdL	Code-switching EvdL
80 Matthew	Mela **cotton** madwarha. Then **cotton** around it!	SLog	Code-switching EvdL
81 Noel	Jien kont qed naħseb forsi nibnu xi struttura u l – bajd jinżel fuqha. I was thinking of maybe building a structure and the eggs will land on it.	SLog	Maltese
82 Keith	Nistgħu nwaddbuha minn għoli ta **half a metre**. We can drop it form a height of **half a metre.**	SLog	Code-switching EvdL
83 Noel	Xorta tinkiser fuq **tray** vojt. Tiftakar li nkisret fuq il – bank minn għola ta **30cm**? It will still break on an empty **tray**. Do you remember that it broke on the bench from a height of **30cm**?	SReb/ SReb-PM	Code-switching EvdL
84 Robert	Forsi nistgħu nimlew il – **bowl** bl- ilma? Maybe we can fill the **bowl** with water?	SAsQ/ SAsQ-Log	Code-switching EvdL

85 Noel	Irridu nipproteġu l – bajda. Ġieli raju xi struttura magħmula mill – qasab fuq youtube biex tipproteġi l – bajda? Xi ħaġa hekk. We have to protect the egg. Have you ever seen a structure made out of cane on youtube to protect an egg? Something like that.	SRQ/ SRQ-EvdL SAsQ/ SAsQ-Log	Maltese
86 Matthew	Nistgħu nagħmulha fl – i**slime**. We can put it in slime.	SRQ/ SRQ-EvdL	Maltese
87 Keith	Jekk nagħmlu ħafna **slime** madwar il – bajda, tkun qisha tip ta protezzjoni. If we put a lot of **slime** around the egg, it will be a sort of protection.	SElb/ SElb-EvdL	Maltese
88 Noel	Ejja naħsbu f'xi ħaġa oħra, ħalli jekk tinkiser meta tkun fl – i**slime**, xorta nkunu nistgħu nkomplu naħdmu fuq il – proġett. Let's think of something else as well, just in case it breaks when covered in **slime**, we would still be able to work on the project.	SLog	Maltese
89 Robert	Għaliex issuġġerejt l – i**slime**? Why did you suggest **slime**?	SAsQ/ SAsQ-Clr	Maltese
90 Keith	Għax ħabba li qisu **jelly**, **it will absorb the impact**. Because since it is like **jelly**, **it will absorb the impact**.	SRQ/ SRQ-SL	Code-switching SL
91 Robert	Imma kif l – i**slime** ħa jibqa mwaħħal mal – bajda? But how will the **slime** remain stuck to the egg?	SAsQ/ SAsQ-Clr	Maltese
92 Noel	Jekk l – islima jitgħaffeġ, il – bajda xorta tibqa fuqu. If the slime gets squashed, the egg would still stay on it.	SRQ/ SRQ-EvdL	Maltese
93 Matthew	Inġibu bajda mgħollija mid – dar. We bring a boiled egg from home. (giggles)	SOff	Maltese
94 Keith	Imma aħna li l – qoxra ma tinkisirx irridu, mhux li l – isfar ma joħroġx. But what we need is the shell not cracking, and not that the egg yolk doesn't spill.	SLog	Maltese
95 Noel	Li ma tinkiser xejn. Il – qoxra. That it doesn't crack at all. The shell.	SLog	Maltese

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The exchange above shows how the students at first were mainly putting forward ideas without much reflection. They suggested wrapping the egg in a material, mentioning bubble wrap, kite paper or tissue paper. When these ideas were put forward, the students kept on sharing their ideas without either acknowledging or rebutting previous ideas. Such exchanges are considered as cumulative talk

(Mercer, 1995). Only Keith attempted to provide an explanation for his suggested idea (turn 90) and his explanation shows that he was quite focused on impact rather than descriptions around momentum and impact. The students did not even reflect on which material would be the best and why. So, there was limited social construction of knowledge at this point. It was only when Matthew suggested dropping the egg on slime that the students' thinking shifted from presenting ideas to focusing on the suggestion made and attempting to reason out what would happen and why. Noel's contribution demonstrated his awareness of the focus on finding ways how to protect the egg by decreasing the force of impact. Although Keith just stated that since slime is like jelly, '*it will absorb the impact*', his contribution shows creative thinking. His contribution also shows how he related slime (something that gets squashed) to less force of impact. However, he could not articulate it in terms of physics concepts, i.e. slime would increase the time of contact and thus decrease the force of impact. At this point, Reem, who was not part of the participating group, brought to the attention of the whole class that they had made a dough, placed it on the bench and when the egg was dropped on the dough from a height of 150cm, the egg did not break.

The extract shows a similar pattern to previous exchanges where students, when sharing their reasoning, tended to speak in Maltese with interspersed use of English. English was mainly used for key expressions such as "absorb the impact" and measurement terms such as "30cm mark" and "half a metre", which are considered as non-technical terms related to the activity. This use of English was also noted for words which are normally integrated in everyday Maltese language such as "bowl", "tray", "cotton" and "slime", for which there is actually no specific Maltese word for. When Reem (not included in the transcript as not one of the research participants) brought to the attention of the whole class of how they had protected the egg by making a dough, Matthew stated that he was confused. As a result, the discussion moved on to a question and answer sequence between Matthew and myself. This exchange is presented in Table 6.3l overleaf.

Table 6.3l: *Extract 2 from the discussion during Activity 3 Elaboration stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
100 Matthew	Mhux ċert x'irridu nagħmlu? I am a bit lost about what we have to do now.	SUnS	Maltese
101 Tch	Have you asked your group for help? Do you remember what the video was about?	TchI/ TchI-S	English
102 Matthew	Yes, and I understood that the flour absorbed the force of the egg.	SRQ/ SRQ-SL	English
103 Tch	Why did the flour absorb the force/ impact caused by the egg?	TchI/ TchI-E	English
104 Matthew	Cause the flour moved, scattered actually, and the egg kept going in the bowl and the time of contact between the egg and flour was long.	SRQ/ SRQ-SL	English
105 Tch	So, since the flour is soft, and it increased the impact time, it also absorbed the impact, the energy. How can we use this knowledge to protect the egg when it hits a hard surface, like the floor or the bench?	TchI/ TchI-S	English
106 Matthew	U l – għaġina kellha l – istess effett tad – dqiq. And the dough has the same effect of flour.	SRQ/ SRQ-EvdL	Maltese
107 Tch	The dough and the flour had the same effect on the egg, right.	TchI	English
108 Matthew	Ok I get it now. We need to do something so the impact time increases so the egg won't break.	SUKE/ SUKE-SL	English

* words written in Blue denote Maltese words

It is noted that during this exchange with me, the teacher, Mathias spoke either entirely in Maltese or entirely in English. He used the English language mainly when he was explaining what he had understood from the investigation carried out (exploration stage) and to explain what he thought that they needed to do, but he used entirely Maltese to inform me that he was not following and to report his observation. The fact that during the exchange, most of his contributions were entirely in English highlights how Matthew either followed my procedure as I spoke entirely in English or he considered the exchange as a formal exchange. Moreover, this highlighted that my role as a facilitator of learning through posing questions to scaffold and redirect his thinking, Matthew managed to use Physics to explain why the egg did not break when it was dropped on flour.

The discussion then moved on with Noel suggesting to the group to make a dough, test whether it protects the egg from breaking when dropped from a large height and then write how they had protected the egg. The transcript overleaf (Table 6.3m) presents the students' constributions following Noel's suggestion.

Table 6.3m: *Extract 3 from the discussion during Activity 3 Elaboration stage*

Turn No.	Utterance	IBL Main Code & Sub-Code	Language Use
109 Noel	Nagħmlu l – għaġina u nippruvawha umbagħad niktbu kif ipproteġejna l – bajda? Shall we make a dough and try it out and then write about how we protected the egg?	SAsQ/ SAsQ-Log	Maltese
The other group members nodded and the made a dough.			
110 Keith	Ejja nippruvawha minn għoli ta **150cm**. Let's try it from a height of **150cm**.	SLog	Code-switching EvdL
The other group members nodded and while Keith held a measuring tape and Robert dropped the egg.			
111 Yuri	Since the egg didn't break when we covered it in dough, we can write that the dough acted like the crumple zone and absorbed the force of impact. This did not damage the egg like the crumple zone avoids the persons getting hurt in a crash.	SObS/ SObS-SL SUKE/ SUKE-SL	English
112 Robert	We have to add that because the dough acted like the crumple zone, it also increased the contact time between the egg and the hard surface. Then we write your last sentence. Do you all agree?	SElb/ SElb-SL	English
113 Noel	Iva. Yes.	SAck-Aff	Maltese
114 Matthew	Nodded	SAck-Aff	

* words written in Red denote English words used while speaking in Maltese

* words written in Blue denote Maltese words

The above exchange shows that the group members agreed to Noel's suggestion. After testing their idea, the students were required to draw their conclusion about the relationship between contact time and force of impact as a group and write it down. It was observed that there were only 2 contributions: one by Yuri, who had returned to the classroom during the exchange between Matthew and myself, and one by Robert. Yuri was able to explain the physical concept behind their observations by identifying how the dough acted like the crumple zone. He was also able to apply the knowledge gained to explain it (absorb the force of impact). Robert provided a more sophisticated explanation as he recognized the specific relationship between time of impact and force of impact.

The analysis of the elaboration stage shows that out of the 34 contributions the students put forward, they mainly:

- discussed aspects of the task such as what to do and how they carried it out (Slog – 11 times). *Example: I was thinking of maybe building a structure and the eggs will land on it*;
- asked questions seeking logistical responses (SAsQ-Log – 5 times). *Example: Shall we make a dough and try it out and then write about how we protected the egg?*;
- replied to questions using everyday language (SRQ-EvdL – 5 times). *Example: If the slime gets squashed, the egg would still stay on it*;
- asked questions seeking clarification about contributions put forward by peers (SAsQ-Clr – 3 times). *Example: Why did you suggest slime?*; and
- replied to questions using scientific language (SRQ-SL – 3 times). *Example: Cause the flour moved, scattered actually, and the egg kept going in the bowl and the time of contact between the egg and flour was long.*

The analysis of the elaboration stage also highlights how first-language Maltese speakers either spoke entirely in Maltese or code-switched when Yuri was not present, and I as their teacher was not an active participant in the discussion. This is similar to the language repertoires that the students opted for in Activity 2 (Table 6.3c). This means that the students who are more used to talking in Maltese and thus experienced difficulty in expressing themselves in English in the classroom, as well as the students who did not struggle to participate in whole-class or group discussions in English, resorted to using the Maltese language or code-switched when it was possible to speak in Maltese without excluding other students due to language limitations. It is also noted that, on the other hand, during the question-answer sequence between Matthew and myself, Matthew predominantly used the English language. This shows that Matthew considered talking to the teacher as a formal exchange. It is also observed that although the students used different language repertoires when engaged in dialogue, they still resorted to the English language when drawing their conclusion. This further supports that students realise that they need to give formal responses in English as in the case of formal assessment where written tasks and examinations are always in English.

On analyzing this experience, I concluded that:

- ***Presenting a guided/open IBL activity engaged the students:*** This IBL activity was not straightforward as a a guided/open IBL activity as although it provided the students with the key inquiry question, they were not given any cues or help about which factors influence whether an egg will break when dropped through a height nor in identifying factors which they had to keep constant or not, or how to design and carry out the investigation. The students were also evidently getting accustomed to the IBL approach. They were thus more engaged when carrying out the investigation. They were becoming accustomed to talking and discussing as they work.

- ***The students understood the relation between the time taken for colliding bodies to come to a stop and the force of impact:*** The aim of this activity was to implement an IBL activity which enabled the students to understand that increasing the contact time between colliding bodies, decreases the force of impact. The students managed to explain fully their observations during the investigation. This meant that the students' achieved a good level of understanding as I had planned.

- ***There was more talk during the activity:*** I can consider that there was a significant improvement in the degree of talk taking place during the activity, both during the investigation, as well as during the plenary. The quality of the talk also moved from only describing their observations to trying to explain what was happening using scientific language.

- ***The students' language preference appears to influence their choice of language to use:*** Yuri stuck to speaking in English. Although the students who were first language Maltese speakers used the three different language repertoires, they mainly spoke entirely in Maltese and code-switched when referring to specific physics aspects when talking among themselves when Yuri was not present. Talking exclusively in English by first language Maltese speakers took place either when interacting with the teacher or with Yuri, and when drawing conclusions about the investigations carried out. This highlights how the students considered talking to the teacher as a formal exchange and thus resorted to using the formal language of assessment. It also highlights that the students considered Yuri as English speaking and spoke in English to include him in the learning experience. It was mainly Noel who did so during this activity. The students also reverted to the English language when presenting the final formal conclusions of their investigations.

Collating my reflections and evaluation using Kolb's cycle, Table 6.3n below presents a summary of my experience of the third activity carried out, my reflection on the outcomes of the IBL activity, the hypotheses that emerged from the analysis, and my plan for the interview questions.

Table 6.3n: *Research design following Kolb's cycle of reflection – Cycle 2 Activity 3*

Stage 1: Experience	From the third IBL activity during this cycle, I noticed that presenting the students with a guided/open IBL after getting accustomed to an IBL approach and having more freedom in language use, enabled them to engage in more discourse. I can consider that there was an improvement in the degree of talk taking place. I also noted that their language preference appeared to influence their choice of language to use. They were also able to use scientific terminology – force of impact and absorb the impact – well in their responses.
Stage 2: Reflections	This guided/open IBL activity showed that the students were becoming more accustomed to IBL. The students were able to demonstrate their learning. They started slowly to move away from just noting observations to also attempting to present explanations, using correct technical terminology. Allowing the students to express themselves in their preferred language allowed more discussion and social construction of knowledge to take place.
Stage 3: Generalisations/ Hypotheses	The more students experience IBL activities and are afforded opportunities to use their preferred language, the more they learn to talk and engage in social construction of knowledge. They will learn physics concepts better as well as learn how to express themselves in correct scientific way.
Stage 4: Plan	I thus planned to conduct semi-structured interviews to obtain the students' views on learning through IBL and the language use in the classroom.

This chapter has so far analyzed the use of the different language repertoires used by each student during each stage of the 5 E's model of inquiry of the three IBL activities implemented. The findings that emerged are presented in Chapter 7. These findings will be discussed taking into consideration to the students' responses to the semi-structured interview questions which were carried out at the end of the activities (Appendix 14).

Discussion of Cycle Two findings and students' responses

7.0 Discussion of overall findings of the three IBL activities taking into consideration the students' responses

This section presents the findings that emerged from the analysis of the transcripts of the three IBL activities carried out during Cycle Two, together with the findings from the students' responses in the semi-structured interviews conducted on completion of the three activities in Cycle Two.

Following the analysis of the activities, the students' responses in the semi-structured interviews were analysed. The analysis of the students' responses was based on thematic analysis, as I needed to identify patterns or themes in the data that were important and interesting. Then, I used 'these themes to address the research' (Maguire and Delahunt, 2017, p.3353). In this study, it required identifying themes related to effective teaching and learning of Physics, the use of IBL activities, the language used during the lessons, the use of scientific terminology and the role of the teacher. On reading the transcripts a number of times to become familiar with the data, initial codes were generated and then modified to reflect better the key issues which emerged. This process was done by hand, by working through hardcopies and using highlighters. The codes were then examined, and codes related to the same issue converged into themes. Since certain codes overlapped in more than two themes, the themes were reviewed and modified. The final themes which emerged were: language, inquiry, writing, scientific terminology and the role of the teacher. These themes are presented together with those emerging from the analysis of the activities. The aim is to focus on key issues which emerged from the second cycle of data collection.

The insights obtained from the analysis of the activities of Cycle Two and the student interviews show that: language plays a role in the learning process; structured and guided approaches are more effective in bringing about learning when compared with an approach that offers minimal guidance until the students get accustomed to IBL; and that during IBL activities, the role of the teacher is a catalyst in promoting better understanding of physics concepts.

The section below focuses on the themes that emerged from the overall analysis: language, and its sub-themes.

7.1 Theme 1 - The role of language in the learning process

The analysis of the transcripts of the IBL activities showed that:

- ***The type of tasks determined the degree of student contributions and how much student-initiated contributions take place.*** When there was a class discussion, there tended to be less contributions than in the case of groupwork. The type of group activity also influenced the amount of talk taking place. When the students were asked to design an investigation, they tended to speak more. It shows how activities which invited students to provide their own ideas promoted dialogue;
- ***Language preference changed according to the activity type.*** The students were observed to prefer to speak in their preferred language repertoire when articulating their thinking in these IBL activities. The first language Maltese speakers preferred to use Maltese and code-switching for quite sophisticated procedures, such as use of previously acquired knowledge to make sense of their observations, elaboration on their own or their peers' previous contributions and to share their reasoning with and without a scientific concept (e.g. discussing on whether the same person would use more energy if the individual runs up the same flight of steps in less time in the exploration stage of Activity 1, carrying out the investigation in the exploration stage of Activity 1, investigating what happens to white light when it passes through a triangular prism in the exploration stage of Activity 2 and in all 5E stages of Activity 3);
- ***Language use changed according to whether it involved formal Physics or not.*** When the students identified the exchange as formal Physics, mainly when interacting with the teacher or discussing the conclusion and what to write in the worksheet, first language Maltese speakers tended to try and speak in English as much as possible, (e.g. in Activity 2, when I as their teacher asked questions to scaffold their thinking and invite explanations on why they could see colours after the beam of light passed through the prism. Noel stated that '*The prisms reflected the*

light' and later he corrected himself by stating that the prisms '*refracted*' the light);

- ***Students used code-switching more often when struggling to find the right words to express themselves.*** It was noted in all the three activities that when the students struggled to find the right words to express themselves, they tended to revert to code-switching. The type of code-switching taking place was very particular. It was not verbs or adverbs or adjectives which students code-switched, but mainly labels, or words which we do not have in the Maltese language. These included technical ways of talking physics such as '*cm*', '*length*' and '*spectrum*', which, even if they are speaking in Maltese, students will use because that is the way they know how to talk about them. This finding supports the study carried out by Mifsud (2012), who found out that when different language repertoires were encouraged, his participants' contributions consisted of mainly Maltese sprinkled with technical terms (language of science) in English. The students also code-switched words which are often used naturally as part of the Maltese language, such as '*fuel*', '*stopwatch*', '*cupboard*', '*slime*', '*tissue*' and '*bowl*';
- ***Students switched to their preferred language when reasoning things out.*** The students preferred to think/reason things out in their preferred language repertoire when they try to make sense of what they were learning about, in this case, when they were trying to make sense of the physics phenomena in place. The type of thinking process required, appeared to be a major influence of what language the students used. When the students were trying to understand what was happening conceptually, thinking in their preferred language seemed to facilitate the process. This was particularly the case with Robert and Yuri. In instances where Robert was trying to make sense of how physical phenomena work, he switched to Maltese. He did this when: i) considering the correlation between weight and the fuel/energy used; ii) considering how light disperses; and iii) reflecting on understanding of the physics behind crumple zones when dropping the egg on different surfaces. When he addressed the teacher, he made an effort to speak English but often resorted at best to code-switching. Yuri, on the other hand, because he preferred English, even if he understood Maltese, did not try to speak

Maltese, but stuck to speaking entirely in English even when speaking with first language Maltese speakers. Thus, the different levels of proficiency in the language determined the language used by the students when sharing their thoughts and ideas in class. This is similar to the findings that emerged from the study carried out by Garza and Arreguín-Anderson (2018);

- ***Parallel monolingualism also exists in the classroom context***. Noel and Keith can be considered parallel monolinguals as they either spoke exclusively in English or in Maltese. They thus could perform as monolinguals in different languages (Heller, 1999). In fact, both students had a high level of proficiency in both English and Maltese, even if they tended to prefer the English language in most cases;
- ***Language use was influenced by the presence of a foreign student language use***: The group of students in this study included a foreign student who although understood Maltese, he did not communicate in Maltese. The other students made an effort to speak mainly in English or code-switch when interacting with him. The use of English was observed less when Yuri was either absent or out of the classroom or when they were not interacting with him. This reflected the students' awareness of their classmate's language preference and changed their language use to include him in the learning process. Sticking to a language when other students do not understand might exclude certain students from the learning process.

The interviews were carried out with five students. Two of these students participated in the interviews when the interview questions were piloted. Both students had joined my classroom during their second-year learning Physics (Year 10), thus, although they were not part of the participating group of which the transcripts of the activities were analysed, they participated in the three activities implemented during Cycle Two. The other three students were part of the participant group during both cycles and they represented the three possible preferences of language use: Yuri - entirely in English, Robert - mainly in Maltese and code-switching and Keith - a parallel monolingual. When the students were interviewed, Yuri said that he prefers to speak in English even though he understands everything in Maltese, Robert said that he prefers using his native language (Maltese) while Keith, being fluent in both English and Maltese stated that it does not matter to him. The students' responses to the question '*Do you prefer expressing yourself in English or Maltese in class?*' corroborates and consolidates the conclusion from the activities, that the students' different levels of proficiency in a language determine the language they use during the lesson. Keith's response to the question whether it made any difference to him whether discussions are in Maltese or in English, corroborated and substantiated the conclusions from the activities about the relation between the level of proficiency and the preferred language used. Since Keith was a parallel monolinguist, to him discussions could be held in any language. Yuri, on the other hand, although he stated that the language used during discussions does not matter for him, he never made an effort to speak Maltese, even though he stated that he understood and spoke Maltese. This shows that despite the other students making an effort on many occasions to speak in English when he was present during the activity, he was not sensitive towards the level of proficiency of the other group members. In fact, he even stated that '*if students who do not understand Maltese are present in class, [he] expected the teacher and the students to talk in English*'. Robert's response was surprising. Since he tended to speak in Maltese and by code-switching and his proficiency in English was low, I expected him to state that he preferred the discussions to be in Maltese. However, he stated '*Now no, not at all. I understand both and the discussions in Physics helped me become more confident with talking in English.*' He also acknowledged that he needed to learn how to express himself in English when doing physics and so had to learn the language of Physics in English. His response shows that he was aware of his proficiency in English and considered discussions in English as beneficial to improve his proficiency in the language. It also shows that allowing the students to reason in their preferred language might enhance their proficiency in the language of assessment (English). A basic level of proficiency in English is required for students to perform well in formal assessments in Physics, as English is the official language of assessment. Robert's awareness about his proficiency in English and the importance of being fluent in English to perform well in formal assessments was also reflected in his response to the question '*How do you feel about the type of language used in the Physics classroom? (Do you prefer the teacher to talk in Maltese or in English?) Why?*' as he stated that '*since the exams are in English, I prefer that the teacher explains the important points in English.*

It helps me know how to say things properly'. This shows that teachers of science subjects are also language teachers (Tan, 2011).

The analysis of the activities also showed that the students contributed more to the discussions when they were working in groups than in whole class discussions or when the discussions were teacher-led. Thus, these activities showed that they can promote dialogue and enable the students to socially construct knowledge (Huerta and Jackson, 2010). Discussions play a vital role in an inquiry-based learning approach, as during these discussions, the students are expected to share and construct knowledge (Wellington and Osborne, 2001). The students' responses to the question '*How do you feel about talking/discussing in the Physics classroom?*' further substantiate this finding. Robert stated that he considers the discussions as opportunities '*to learn even more*' as the discussions enable them [students] to add more knowledge to what they '*already know*'. Keith and Yuri's responses were more elaborate. They both explained that they consider discussions useful as when they share their opinions, they have to ensure that the other group members understand their contributions and thus, in attempting to do so, their explanations '*make more sense*' to them as well. This shows how being able to verbalise their thinking enhances the students' understanding, which is in line with how Vygotsky explained the relation between thought and language. Yuri also described the discussions as a good opportunity to learn how to '*talk science*'. Lemke (1990) pointed out that effective learning can be considered to have taken place only when the students are able to talk science. It is interesting that Yuri is aware of this.

During Cycle Two, the use of the Maltese language and code-switching among first language Maltese speakers increasing. The number of sequences initiated by questions posed by me as their teacher decreased. Students' initiation of sequences increased significantly over the period in which this study was carried out, possibly because, the students were allowed to discuss in their preferred language repertoire.

Tables 7.0, 7.1 and 7.2 overleaf show the number of contributions put forward in the three different language repertoires, i.e. solely in English, solely in Maltese or by code-switching, by every student as well as myself, as their teacher during the three IBL activities carried out during Cycle Two.

Table 7.0: *Contributions put forward in the three language repertoires in Activity 1 Cycle Two*

Name	Contributions in English	Contributions in Maltese	Contributions by CS	Total
Robert	6	5	17	28
Noel	11	5	6	22
Matthew	0	9	2	11
Keith	-	-	-	Absent
Yuri	19	0	0	19
Teacher	6	0	0	6

Table 7.1*: Contributions put forward in the three language repertoires in Activity 2 Cycle Two*

Name	Contributions in English	Contributions in Maltese	Contributions by CS	Total
Robert	6	8	20	34
Noel	9	6	6	21
Matthew	-	-	-	Absent
Keith	12	5	10	27
Yuri	-	-	-	Absent
Teacher	11	0	0	11

Table 7.2: *Contributions put forward in the three language repertoires in Activity 3 Cycle Two*

Name	Contributions in English	Contributions in Maltese	Contributions by CS	Total
Robert	3	3	14	20
Noel	3	8	3	14
Matthew	5	7	3	15
Keith	0	3	6	9
Yuri	14	0	0	14
Teacher	12	1	0	13

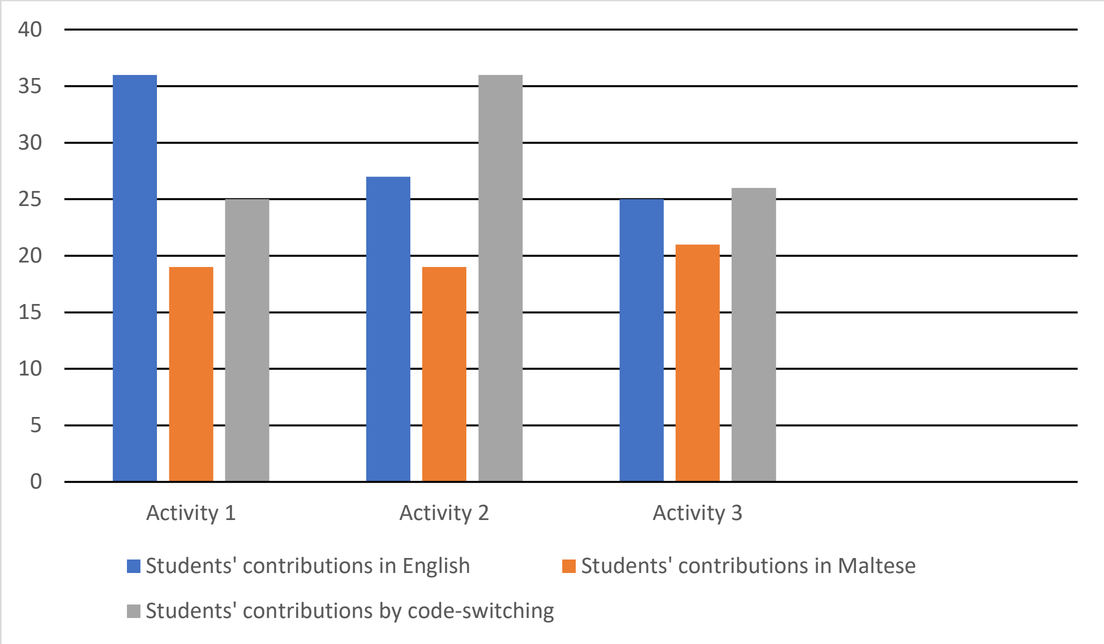


Figure 7.1: Students' contributions in the three different language repertoires during Cycle Two

The above figure shows that the students' contributions by code-switching were predominant during Activity 2 and Activity 3 when compared with the contributions put forward either in English or in Maltese. Although there is a possibility that one activity stimulated fewer contributions than another, this study still supports the conclusions drawn by many researchers worldwide: that in a bilingual context, learning science in one's second language, is an additional hurdle for the students (Msimanga and Lelliott, 2014) and thus, students should be allowed to use their preferred language to verbalise their scientific knowledge and understanding.

The first theme that emerged thus highlights the importance of creating classrooms which value as well as allow opportunities for different language repertoires to be used, as otherwise, valuable inputs to the discussions may be lost (Garza and Arreguín-Anderson, 2018).

Since the use of different language repertories took place in an inquiry-based setting, the next section discusses the use of inquiry-based learning activities, which is the second theme that emerged from the thematic analysis of the interview responses.

7.2 Theme 2 - The use of inquiry-based learning activities

The analysis of the transcripts of the IBL activities showed that:

- ***structured and guided approaches are more effective in bringing about learning when compared with an approach that offers minimal guidance if the students are not accustomed to an IBL approach***. This is in accordance with how Hmelo-Silver, Duncan and Chinn (2007) and Kirschner, Sweller and Clark (2006) describe the effects of structured and guided approaches to learning (section 2.9). This can be concluded as the students were able to put forward their ideas and bring to the classroom previously acquired knowledge to make sense of the phenomena they were presented with during these three IBL activities. Thus, the students were able to connect ideas and formulate them in a meaningful way. Thus, they were able to socially construct knowledge about the phenomena with which they were presented. It was only after practice in structured inquiry, which enabled the students to get accustomed to an IBL approach, that the students could engage in more discourse during a guided/open inquiry activity. This also shows that my insight from Cycle One, that the students need the learning to be customised and scaffolded was in the right direction with this group of students. In fact, the discussions during the plenary parts of the three activities implemented in Cycle One, were more of a question - answer sequence between myself as their teacher, and the students (tables 4.1, 4.6 and 4.9).

As a result of the above-mentioned insights, I can say that adopting an inquiry-based approach, which is sensitive to the language use in the learning process promoted better understanding of concepts with these students. The first interview question about the use of IBL sought to find out the students' views of their engagement in the first IBL activity. The students were asked the following question '*How did you feel during your first inquiry activity?*', specifically to find out whether they enjoyed these types of lessons. While enjoying the lessons is not a precondition to learning, I believe that it can be considered as a supplement. The students were clear and consistent about engaging in IBL activities. They stated that such opportunities instilled some form of '*excitement*' and enjoyment. Their responses reflected how much these three students appreciated the freedom to move around instead of just sitting down. They also valued the opportunity to talk and share their opinions instead of listening only to what the teacher had to say. I also wanted to know whether the students considered IBL activities as opportunities that promoted better understanding of physics concepts. Thus, the second question related to the use of IBL activities was '*How do you feel about inquiry activities in the Physics classroom now that you have experience learning through a number of these activities?*'. This question sought the students' views of IBL in relation to learning after having participated in a number of IBL activities in the Physics classroom for the previous two consecutive scholastic years. Robert described these activities as '*a great way to learn Physics*' as they '*learned something new*' every time they were presented with an activity. Keith stated that there should be more inquiry-based activities as they have helped him concentrate more since he wanted to write '*proper conclusions*'. Thus, he paid more attention. He further described the IBL activities as an opportunity where students learn from one another, which makes Physics '*easier to understand and remember*'. Yuri's reply not only showed that inquiry-based activities make learning Physics easier for him as well, but that for him, inquiry-based activities also help certain students '*relate the theory to something in real life*'. To substantiate his belief that inquiry activities make learning Physics easier, he referred to the last activity where they had carried out the Egg Drop – make it land safely activity (description of this activity can be found in section 6.6). He stated that the activity '*was not only fun, but it helped us think on what we had learnt in forces and their use in real life, especially when from the effect of dropping an egg from different heights onto different materials, you can understand something big, like the effect of forces during a car accident*'.

The last question which focused on inquiry-based learning approaches was '*Are there ways in which the inquiry activities have helped you to learn Physics?*'. The responses provided by the three students to this question also corroborated and consolidated what I concluded from the activities, that inquiry-based activities promote better understanding of physics concepts. This is so because although the students provided different reasons, the three of them stated that these activities helped them in learning Physics. In fact, Robert considered these activities as opportunities where he could not only '*put the theory to the test*' with the other students, but also because they '*had to talk about the physics that was* *happening*'. In addition to stating that these activities have helped him understand Physics more, Keith mentioned that they also enabled him to learn '*how to write things better*'. Since he did not specify in what ways they have helped him improve his writing, he was asked to explain what he meant by '*writing things better*'. Here he replied that these activities taught him to write as if he is '*explaining things to someone new in class*', by giving '*easy information and then use the terms*' learned in Physics. This reason of learning how to explain things as if someone new joined the class was also highlighted by Yuri. In fact, Yuri stated that these activities have helped him understand and learn the way things should be explained. He also highlighted that learning how to explain things in this way has helped him '*do better in exams'* because a result of these activities, he learned '*the technique of giving a proper and detailed answer*'. He further pointed out that the activities helped him '*relate the Physics to the real world*'. For him, the opportunity to '*build the information together*' and the way I as their teacher posed questions during the activities have helped him '*think better*' and '*remember more*'.

The second theme that emerged thus highlights that adopting an IBL approach which is sensitive to the language used, facilitated better understanding of the physics concepts, thus, the language used promoted learning (Garza and Arreguín-Anderson, 2018) among my students. It also highlights the power of social construction of knowledge (Abd-El-Khalick, et al., 2004), as much of my students' learning was gained through interaction with others who are more or differently knowledgeable in some way (peers or teachers), but functioning within their 'zone of proximal development' and so making that learning accessible, which is consistent with Vygotsky's social constructivist theory of learning. Furthermore, the findings that emerged from the students' responses to the interview questions show that the students also felt that they learnt language skills – how to talk science in a direct and simple way. It also sheds light that such an approach enabled the students to perform better in tests assessing long-term retention of information (Ruhl, Hughes and Schloss, 1987; Schmid and Bogner, 2015; Low, 2016 and Keithsson, Larsson and Jakobsson, 2019) as they improved their skills in thinking as well as in talking science.

7.3 Theme 3 - Writing in Physics

Research has shown that students need to be competent at interpreting and creating science texts (Norris and Phillips, 2003) to be considered as scientifically literate. Therefore, the students also need to be able to talk and write science (Lemke, 1990). Since students in Malta are formally assessed in writing, it was important to see whether engaging in discussions, which are fundamental in an inquiry-based setting also enabled the students to learn how to express themselves when writing Physics. The group's written conclusions for the three IBL activities respectively were as follows: '*the teacher has to run up the stairs fewer times than the students to burn off the same amount of calories since she weighs more than the students*'; '*when white light entered the prism, the beam of light was refracted and it produced the colours*'; '*since the egg did not break when we covered it in dough, the dough acted like the crumple zone. Because the dough acted like the crumple zone, it absorbed the force of impact and increased the contact time between the egg and the hard surface*. *This did not damage the egg like the crumple zone avoids the persons getting hurt in a crash*'. The insights obtained from the transcripts of the three IBL activities thus show that providing the students with opportunities to engage in discussions within an inquiry-based learning setting, enabled them to learn how to create scientific text. This is concluded as it was noted that the students were able to draw and write appropriate conclusions to the three IBL activities implemented in Cycle Two. The students' responses to the question '*How do you feel about the writing used in the Physics classroom (what you write and what the teacher writes)? For example, when doing experiments and writing the conclusion*', substantiate my conclusion that engaging in discussions within an IBL setting enabled the students to learn how to create scientific text. This is so because Robert and Keith considered the IBL activities and experimental work as tasks where they had to pay attention to what they were doing in order to document what they did and how and why they did it. Yuri stated that writing helped him understand more. This is possibly because he was English speaking and thus, reflecting on what was learnt and writing it down as part of the conclusion in his first language was easier for him than it was for Robert, who preferred to speak mainly in Maltese and for Keith, who although was fluent in both languages, was Maltese speaking.

7.4 Theme 4 - Learning and using scientific terminology

As discussed in section 2.2, for students to be considered scientifically literate, they need to be able to talk and write science effectively and to do so, they need to learn the scientific terminology (Farrell, 1996; Wellington and Osborne, 2001). Thus, this study also looked at whether adopting an IBL approach promoted the use of scientific terminology correctly and cogently. The transcripts of these three IBL activities show that the students were aware of the importance of using scientific terminology correctly, as they made an effort to use the right scientific terminology when sharing their reasoning, with the exception of Noel. During the second activity – Exploring Light through Prisms, Noel used the words 'reflection' and 'refraction' interchangeably and only after engaging in the discussion (Table 6.2g) Noel showed that he knew the difference between the concepts of reflection and refraction. In this case, one can argue that he had either mistakenly used them interchangeably in his earlier contribution or it is an evidence that word meaning develops (Vygotsky, 1987) and became clearer and deeper, with usage, and exposure to potential critique from his peers and teacher, over time. Thus, the transcripts also show that engaging in discussions within an IBL setting can be considered to be one of the most valuable vehicles for the students to learn scientific terminology (Huang, 2006). The students' responses to the interview question '*How do you feel about the scientific language (words/terms which are scientific?)*' consolidates the conclusion that the students are aware of the importance of knowing scientific language and that they also value knowing how to use them correctly. For Robert, this will make the subject easier while for Keith and Yuri, it is beneficial for formal assessments as it will enable them to '*understand the questions better*' and '*write better answers*'. Since the students need to know how to use scientific terminology correctly, it was deemed important to seek their preferred way to learn these terms alongside their preferred way to learn Physics. Thus, the students were asked '*What can you say about the difference between learning Physics using everyday language and then learning the scientific terms or learning Physics using scientific terms only?*'. In their responses, the three students stated that they would prefer to learn Physics using everyday language and then learn the scientific terminology. Keith and Robert argued that their experience of having a teacher repeating what they said using everyday language and then saying it '*using scientific terminology*' not only helped them understand Physics better, but also helped them to remember the terms '*well*' and '*how to use them too*'. Yuri stated that learning Physics using everyday language and then learn the scientific terminology have helped him learn what the terms actually mean. In addition, he highlighted that, as a result of learning the terms in this way, he has become skilled at using them properly when talking, when '*writing an experiment*' and even in '*his answers to an exam question*'.

The fourth theme that emerged highlights how the teacher has a pivotal role in guiding the students and supporting them in learning how to use scientific terminology correctly (Huang, 2006). This is not the only role of the teacher in an IBL setting. Thus, the teacher's role in an IBL setting is discussed below, which is the last theme that emerged from the thematic analysis of the interviews and the activities.

7.5 Theme 5 - The role of the teacher in an IBL setting

The analysis of the transcripts of the IBL activities showed that:

- my role as the teacher was a catalyst to eliciting students' reflections by purposely designing questions in the worksheet (e.g. the following question in Activity 1 'From your group, who used more fuel and who generated more power? Explain. ***(Hint: The distance moved was the same for each member of the group)***' enabled the students to reflect that since the distance was the same, the variable factor was the body weight (table 6.1f); in Activity 2, the students' thinking about what causes a spectrum was directed through the following questions '*What do you think the colour of the beam will be on emerging from the slit? Explain why' and 'What do you think will happen to the beam after it leaves the prism? Explain your answer*'; In Activity 3, the students were guided to make connections between their observations and what they had observed in the video in the engagement stage of the 5E's model of inquiry to draw conclusions about the relation between the force of impact and time of impact through the following statement '*Consult with your group on how the observations correspond to the mechanisms of safety equipment in vehicles*');

- when I as their teacher intervened during these three activities by posing questions either to direct the students' thinking or to invite further elaborations on their previous contributions, the students' contributions shifted from reporting directly their observations to explaining their observations and elaborating on each other's contributions. Thus, the students socially constructed knowledge (e.g in explanation stage of Activity 1 when the students were discussing who generated more power and why; in the exploration and explanation stages of Activity 2 when the students were discussing why a spectrum is produced when white light passes through a prisms; and in the exploration stage of Activity 3 when the students were carrying out the investigation to test the factors which cause an egg to break when dropped on different surfaces);
- creating opportunities in our classrooms which value as well as allow opportunities for different language repertoires to be used.

As a result of the above-mentioned insights, I can say that the role of the teacher in skilfully designing questions in the worksheets and asking open-ended or divergent questions to encourage and stimulate student thinking and reasoning, can serve as scaffolding to support students' development of conceptual understanding (Smart and Marshall, 2013). Moreover, the teacher has to be sensitive to the students' proficiency in the language of assessment. Thus, the teacher has to create classroom spaces where different language repertoires are encouraged and valued, otherwise the strict use of the language of assessment, which might be more of a second language to many students, might 'severely restrict the possibilities open to students to contribute thoughtfully' (Skidmore, 2006, p.507) to the discussions, which are fundamental in an IBL setting. The students' responses to the interview question (question 10) support the insights obtained from the transcripts of the three IBL activities regarding the teacher's role as a scaffolder by asking questions. This is so because Robert, in his response, made reference to how much harder it would have been for them to carry out the activities if I had not helped them or asked them questions which made them think about how to do it. Keith also made reference to the type of questions I posed. He stated that the way I posed questions and guided them to draw appropriate conclusions helped him learn how to give proper explanations. Yuri's response was similar to Keith's response. For Yuri, the way I posed the questions helped him '*think better*'. Thus, the students' reference to the way I posed questions corroborate the insights obtained from the IBL transcripts. Regarding the use of language, the students expressed that they prefer the teacher to use everyday language and then use scientific terminology. Moreover, Robert, in his response to question 4, stated that he prefers the teacher to use both English and Maltese, but he prefers the teacher to explain '*the important points in English*' as it helps him know how to say things properly. This shows that for students who are not highly proficient in the language of assessment, they prefer the teacher to explain in their preferred language and then shift to English so that they would know how to respond in the language of assessment. Thus, such a response substantiates the importance of being sensitive to the students' proficiency in the language of assessment, and also, the importance of valuing the different language repertories so that the students can socially build knowledge.

The fifth theme that emerged thus highlights the pivotal role of the teacher in an IBL setting in skilfully designing questions to scaffold the students' thinking. It also involves being sensitive to the students' proficiency in the language of assessment, in order to promote better understanding of the physics concepts as well as improve their proficiency in talking science.

Theoretical Interlude

As suggested at the end of chapter 2, through sustained engagement with my data, the potential for theoretical insights became apparent. I came to appreciate first, the relevance of Vygotsky's work around language as a fundamental took of social cognition; and second, my grasp of the (dynamic) roles of the group endeavours in my physics classroom was enriched by using perspectives from Lave and Wenger's (1991) 'communities of practice' work, and especially, the 'communities of inquiry' idea linked to Lave and Wenger's work that emphasises the social quality and contingency of knowledge formation in the sciences, as further developed by Garrison et al. (2000 on). These two theoretical tools provided significant illumination, so I expand on them at this point.

As explained in section 1.7, I wanted to promote a student-centred approach to help my students overcome their struggles when learning Physics and thus promote better understanding of physics concepts. This study acknowledges that the students bring everyday knowledge to the classroom learnt through everyday experiences. This knowledge, referred to by Vygotsky as spontaneous concepts, is 'deeply rooted in the child's experience' (Vygotsky, 1934, p.158) and the child can use these concepts to solve problems.

Since these concepts are not necessarily aligned with scientific understanding, teaching the students scientific concepts in class will help 'restructure and raise spontaneous concepts to a higher level' (Karpov, 2018, p.103). However, teaching the students the scientific concepts in a traditional way, might only result in the students being able to memorise the definitions of these scientific concepts as they might not be able 'to apply the concepts to solve subject-domain problems' (ibid., p.104) and incorporate them into their mental scientific 'schema' For students to be able to do so, Karpov (2018) explains that teachers should adopt the version of Vygotsky's theoretical learning approach advocated by Gal'perin (1985) (cited by Karpov (2018)), by creating a problem-situation, providing definitions for reference and the procedure to follow, which might not always be ready made. This theoretical learning approach is similar to a structured and guided inquiry-based learning approaches as in these approaches, the students are given the problem, are provided with the necessary materials to solve the problem and are provided with the method in a structured approach while the students have to think of a method in a guided approach. This study thus also reinforced my previous experience, underpinning my inclination to inquiry-based learning, where much of my students' learning is gained through interaction with others who are more or differently knowledgeable in some way (peers or teachers). This is consistent with Vygotsky's social constructivist theory of learning, which is different from theories that ‘cast learning as a one-sided process in which only teachers or learners are responsible for learning, either through transmission of knowledge from experts or acquisition of knowledge by learners by themselves (Ragoff, Matusov and White, 2000, p.373). Importantly, in Vygotsky's framework, much of this social learning is mediated by language, on the part of both the more- and less-knowledgeable participant. For Vygotsky, language plays a powerful role in shaping thought and development of appropriate (here, both dialogic and scientific) language can become a powerful foundation for complex cognitive skills such as processing scientific concepts.

Further, the cultural and social context, including the classroom ethos, are critical to the learning that takes place. In this study, I intentionally wanted to move from an approach where as their teacher, I was seen as the one responsible for filling children up with knowledge and students ‘are treated as receivers of a body of knowledge….with little role except to be receptive, storing the knowledge that adults dispense’ (Ragoff, Matusov and White, 2000, p.376). I wanted to establish a classroom culture where all participants are active, which means that ‘no one has all the responsibility, and no one is passive’ (ibid., p.381). I wanted my classroom to function as a community of learners, functioning within a Vygotskyan social constructivist framework, which Ragoff, Matusov and White (2000) explain as a process of transformation of participation where the students take an active role in learning while adults are often responsible for guiding the process (p.381). I believed that such social interactions could also enable my students to borrow the knowledge or skills ‘to perform tasks they would not be able to complete on their own’ (Eun, 2019, p.21) and the amount of scaffolding would provide them with support until the less competent persons can internalise these skills to perform individually (Lave and Wenger, 1991). Within this community of learning, my role as a teacher was that of listening, and intervening, or drawing out for the whole class, key points for learning. This can be understood in Vygotsky's terms as further 'scaffolding' the learning so that students can gradually move from a role of 'peripheral participation' in (here) the scientific discipline, to a more central and knowledgeable role - but language is central to each stage of that, as the teacher probes and the student tries to articulate their present thinking and compare it with others.

Furthermore, based on Vygotsky’s notion of the zone of proximal development (ZPD), which Holzman (2018) describes is often understood to be ‘a characteristic or property of an individual child’ (p.43) and associated as ‘one of the ways that learning-leading-development is a social, not an individual phenomenon’ (ibid., p.42), I believed that adopting an inquiry-based approach would promote better understanding of physics concepts among my students as ‘scientific phenomena are constructed through social discourse’ (Berland and Reiser, 2009, p.28). I therefore believed that as a result of the social interactions taking place during these activities, the less capable would learn ‘through the assistance of another person’ (Holzman, 2018, p.42) who is either the expert in the field or the more capable but functioning within the ZPD. Within this Vygotskian framework, the currently less competent student (the relative level of functioning might not be a permanent or ubiquitous relationship) learns by internalizing the knowledge presented by the currently more competent student and the more competent student also learns, as the interactions will make this student more ‘conscious and reflective’ (Eun, 2019, p.23). With this theoretical framework in mind, I thus believed that through inquiry, I would support my students to construct personal knowledge of physics concepts among themselves (the more capable student would support the less capable student) and with me, as their teacher, the expert in physics concepts, by scaffolding their thinking either through the carefully designed questions in the worksheets or the questions posed during the discussions that take place when implementing the activity.

Discussion and Conclusion

8.0 Introduction

This study has, as a professional teacher, taken me through a journey of pedagogical transformation which, I feel, has helped me improve my teaching and better support my students in their learning process. The analysis of Cycle One helped me realise that while I was improving my skills in delivering IBL activities and the students were becoming more accustomed to IBL, the overall improvement in learning was still limited. Though there were instances where the students demonstrated attempts to present an explanation for their observations, their talk, and consequently their engagement, was limited. There was still insufficient talk among the students for quality constructive learning to take place. Since activities were conducted strictly in English, some students who were not that proficient in the English language experienced a language barrier. This language barrier hampered my students from engaging in sufficient exploratory discussion, limiting the amount of social construction of knowledge which I aimed to elicit during the inquiry activities. Introducing IBL on its own, although improving the learning experience, was not enough. My pedagogy was still too teacher-directed, and I was not utilising the full potential of language as a tool for learning. I felt that it was very important to create a more informal classroom climate, particularly with respect to language use. I learnt to be sensitive to how the language used during an IBL activity impacted my students' ability and willingness to verbalise their scientific ideas, knowledge and understanding (Garcia, 2009; Cummins, 2005). As a practitioner and a researcher, this research made me explore whether the students were more likely to engage in discussion and increase their social construction of knowledge if they were encouraged and allowed to use a language they were comfortable with and which they could use without being language self-conscious compared to the official language of instruction. It was refreshing to have these in-depth professional reflections on my practice. Not only did they help me to understand better why I was using specific pedagogical approaches, but I also learnt to look at other aspects of learning during the teaching process. This helped me move forward in my profession as a teacher and in improving specific aspects of classroom learning.

This study did not only help me with my professional development, but it has also consolidated the argument in favour of the benefits of action research on the teaching and learning community with respect to learning Physics through IBL and in a bilingual context as well as how action research can act as a tool for teacher professional growth (West, 2011) and the transformation of students' learning experiences (Seinuk Cicek, Ingram, Friesen and Ruth, 2019) as well as raises issues about the language of instruction within a bilingual classroom context.

The chapter reviews and discusses the implications of the findings of this study in light of the relevant literature. It considers emerging issues related to the impact of using inquiry-based learning activities on: learning Physics; developing the language of science (Carlsen, 2013); the role of the language used in the learning process (Feser & Höttecke, 2022), code-switching (Msimanga, 2015) and translanguaging (Poza, 2018). The discussion is framed within the study's original primary research question: Does an inquiry-based approach enable students to construct knowledge of physics concepts among themselves and with their teacher, even when learning in a language that may not be their preferred language?

The key results of this research highlight severe limitations to learning when students are constrained to learn in their second language. Implementing a student-centred approach on its own was not enough. There is a strong argument in favour of being sensitive to the students' language proficiency when deciding on the language of instruction to use. This study strongly suggests it is wiser to depart from the official use of the English language for instruction and instead to take on an alternative approach which better responds to the students' existing linguistic capabilities. This approach led to significant increase in my students' engagement in their learning as a response to my main research question. Therefore, it then became important to introduce the research question below, as a consequence of this pedagogical move in my classroom:

- How does a bilingual approach impede or support students in constructing knowledge of physics concepts in a linguistically-mixed group?

The discussion below is directed by five key issues about teaching and learning that emerged from the analysis of the IBL activities carried out in both Cycle One and Cycle Two, as well as from the students' responses to the semi-structured interview questions reported in the previous chapter i.e., Chapter 7.

In line with the objectives of this study, these issues relate to the use of IBL and the students' preferred language for learning in a bilingual classroom, and their implications to pedagogy for policy makers.

8.1 Benefits of action research for the learning community

The first key issue refers to the benefits of action research to teachers' professionality and in achieving effective learning among students. Undertaking action research in education is defined as a means through which practitioners study their own institutions (Johnson, 2012). It is considered as 'one powerful tool for improving the quality of teaching and learning within a school community' (Tillotson, 2000, p.32). As in the case of my personal research journey, this research supports the argument that action research can help teachers improve their pedagogical responsibilities. It can also help schools to understand and improve the quality of the educative process (Johnson, 2012). Action research has the potential to offer 'beneficial opportunities for professionals working within the teaching profession' (Hine, 2013, p.152), such as facilitating the professional development of educators and increasing teacher empowerment. These can in turn be beneficial for the students, as action research can enable teachers to be transformed in terms of their professional competences. This means that through action research, by studying and evaluating their own practice, teachers can: develop new knowledge directly related to their classrooms (Henson, 1996); expand their pedagogical repertoire by learning new ideas on how to improve the lives of the students (Mills, 2011) and how to research their own practice by putting them 'in charge of their craft' (Hine, 2013, p.153). This study has shown that promoting reflective teaching and thinking through action research can lead to 'positive changes concerning the educative goals of the learning community' (ibid., p.153).

8.2 The role of language in the learning process

This study raises a number of issues related to language use in learning Physics. It indicates a greater science learning impact when allowing second language learners to use their preferred language when discussing and trying to understand concepts. Significant limitations to language proficiency appear to interfere with constructing scientific knowledge, learning and understanding. This research highlights the need to teach students the official language of science and the language of instruction, and the importance that the students too are aware of this.

Language has been described as a powerful tool to learn (Pierce and Gilles, 2008) in several research papers focusing on linguistics (Vella, 2109) as well as on pedagogy (Lemke, 1990). The findings of this study have shown that the discussions that took place during the inquiry-based activities organised with my class promoted dialogue, which is fundamental in classrooms (Barnes and Todd, 1977) as it gives students a chance to voice their opinions and share their thoughts and so to support concept formation. This was so as these discussions provided the students with opportunities to use the knowledge learned from both previous lessons as well as in their everyday experiences. This study highlights how students can talk science when they are required to engage in formal discussions (Huang, 2006). It further showed that when already-known concepts were presented and discussed, students can use non-technical language - words which are not part of the Physics repertoire (Harlow and Otero, 2006) as well as the language of science (technical language) – words which have a specific meaning in Physics, which is different from their everyday meaning (Farrell and Ventura, 1998). The instances where non-technical language was used during the IBL activities, indicated that when students discussed in their preferred language, they demonstrated better understanding which helped them develop skills to make connections and to recontextualise knowledge (see transcripts in Table 6.1c and Table 6.1f). This study showed how such instances can provide students with opportunities for meaningful learning to occur (Ausubel, 1963), as they enable students to connect ideas and formulate them in a meaningful way.

Vygotsky points to the symbiosis between everyday language and the development of technical (here, scientific) language: ‘The boundary that separates these two types of concept is fluid. In the actual course of development, it shifts back and forth many times. The developments of spontaneous and scientific concepts are closely connected processes that continually influence one another’ (Vygotsky, 1987, p.177). This mirrors my conclusion that students benefit when they draw on their experience and their resources of non-technical language (everyday speech and everyday concepts) as part of the process of understanding scientific concepts which they encounter in their Physics lessons. This insight has particular application in a bilingual context; it also has resonance, though, in any educational context, to the extent that almost every classroom involves an encounter between the language and culture of the home and community and the language and culture of the school, including the disciplinary language and culture.

The study shows that the language which students use in learning may influence their level of interaction and consequently learning and understanding. The implication is that students' preferred language appears to play a crucial role in the learning process as it limits/facilitates verbal exchanges, and consequently learning as language plays a powerful role in shaping thought and development of appropriate (here, both dialogic and scientific) language (Vygotsky). This is demonstrated through the student exchanges, which increased in quality and quantity as they were free to speak in their preferred language. In fact, the number of contributions put forward by first language Maltese speakers increased when compared with their contributions when they were asked to stick to using solely the English language (Cycle One). The contributions put forward by first language Maltese speakers show that Maltese and code-switching (definition of code-switching is provided in section 2.2.2) were used for quite sophisticated procedures, such as use of knowledge, elaboration and to demonstrate their reasoning with and without a scientific concept. This shows that when the students are familiar with the language they use to discuss, there is greater possibility for them to engage in the social construction of knowledge without the teacher’s assistance (Heugh, 2015; Garcia and Wei, 2014).

Many researchers worldwide acknowledge that in a bilingual context, learning science in a language which is a second language for the students can be a hurdle for the students (Lodge, 2017; Nyika, 2015; Miller, 2009; Rollnick, 2000) and others argue that students should be allowed to use their first language (Msimanga and Lelliott, 2014). Despite this, there is limited research on whether students in the Maltese context who tend to struggle with understanding concepts in a second language would do better if they were allowed to use their preferred language in class or in assessments. Local studies which investigated the language used in the classroom during lesson delivery demonstrated that when the language of instruction is different from the students' first language, it hinders co-construction of knowledge between the students and the teacher as well as between the students (as suggested by Borg, 2010). When different language repertoires were encouraged, the participants contributed mainly in Maltese and used English for technical terms (consistent with Mifsud, 2012). Thus, though the study underpinning this thesis is limited to one group only, it consolidates the findings that emerged in earlier local studies and it can also be assumed that it has contributed to a gap in knowledge in the Maltese context, where students were able to demonstrate their scientific understanding through talk when the use of different language repertoires was encouraged. Thus, allowing first language Maltese speakers to use language they feel more comfortable with in formal assessments might provide a better picture of the number of students who are scientifically literate.

8.3 The use of inquiry-based learning activities to learn Physics

This study showed how adopting an inquiry-based approach to learning Physics can enable students to construct knowledge. This is consistent with other similar research by Smart and Marshall (2013), Furtak et al. (2012) and Abd-El-Khalick, et al. (2004). Although this aspect was not the main focus of my final study, the result that using an inquiry-based approach promotes understanding is to be acknowledged. Not only did the students demonstrate understanding, but there were instances where they were able to construct knowledge among themselves independently, without the need of the teacher's presence and scaffolding. This was achieved mainly when I presented the students with situations and challenges to inquire about phenomena which provoke reflection and consequently the construction and understanding of concepts (Gatt, 2005). This study highlights the teacher's crucial role, particularly with respect to deciding when to 'connect' with and to 'disconnect' from discussions in order to allow students the space to engage in problem-solving and reasoning between themselves (Kriewaldt et al., 2021). This study shows how teachers need to give students plenty of time to use their own experiences when making sense of situations and as they solve open ended physics problems in groups. The students' everyday experiences can support class learning. This was particularly the case in the student group talk which allowed students to enhance their physics reasoning (as in Enghag, Gustafsson and Jonsson, 2007). In the case of this study, careful attention was also paid to how the students were grouped together to ensure that the group members worked well together (as recommended by Schmitz and Winsekl, 2008). This study thus provides insights on how groupwork in inquiry can be used to provide opportunities for students to use their 'existing knowledge' to make sense of new situations, using and practicing their understanding of Physics concepts. It is not enough to provide time for talk, but to also ensure that the groupwork time is set to allow meaningful construction of knowledge to take place.

This study also highlights the need for the students to possess a degree of background knowledge or to be scaffolded to able to make connections between previously acquired knowledge or their observations during the inquiry and when drawing conclusions about the context or content they are presented with (as evidenced by Hmelo-Silver, Duncan and Chinn, 2007; Wood, Bruner and Ross, 1976). In the structured approaches, the students were provided with the problem, the method and the materials to solve it. In the guided approaches, the students were given the problem and the necessary materials, but they had to design the appropriate problem-solving strategies and methods themselves (Colburn, 2000; Staver and Bay, 1987). Both approaches were found to be more effective in enhancing learning compared to minimal guidance. This is in accordance with Hmelo-Silver, Duncan and Chinn, (2007) and Kirschner, Sweller and Clark, (2006) when describing the effects of structured and guided approaches to learning. For example, in Activity 2 of Cycle Two (Exploring Light through Prisms), the students were already familiar with the colours of the spectrum of white light through their interactions with everyday experiences. This enabled the students to engage in discussions, bring their everyday experiences to the classroom, to make connections and recontextualise their knowledge and understanding. Also, in Activity 3 of Cycle 2 (Egg drop – Land it safely) the students discussed and reflected, with the scaffolding provided by my questions on how Newton's second law of motion determined whether the egg would land safely or no. The students were then easily able to make connections between what they had observed (the effect of time of impact illustrated by cars in the video, and whether an egg breaks when dropped on different materials) and their previously acquired knowledge (momentum, force of impact, Newton's first and second laws of motion). These examples show the importance of presenting students with practical situations, and the value of guiding the construction of knowledge which is based on their previously held ideas.

This study has also shown that with practice, engaging in an inquiry approach can help students develop the skill of articulating an explanation. As pointed out in chapter 6, there were some instances where the students built on what they had said earlier, using earlier constructions to reach new levels of understanding (Darling-Hammond, et al., 2020). There were also occasions when the students elaborated on what the other group members had said. When the students were discussing why they still observed colours on the surface of the bubble if everything in the classroom were painted white, the students referred to what they had learnt in previous lessons with respect to a 'beam of light passing from one material to another material' and the experiment of when 'the beam of light was bent on passing from air through the semi-circular glass block'.

This study thus demonstrated that language skills, enable students to articulate their ideas clearly (as evidenced also in Mercer and Dawes, 2008). With more engagement and more talk about science, students can develop linguistic skills to verbalise and demonstrate their understanding. However, this does not necessarily mean that this is enough to learn science. Inquiry is able to present opportunities to provide a concrete example of abstract physics concepts. Students have the freedom to use their preferred language to demonstrate their understanding of science through talk.

The students also learned how to value the importance of elaborating their statements to help the rest of the group understand their ideas (see Robert's contributions in turns 13 and 16 in Table 6.3b and Keith's contributions in turns 87 and 90 in Table 6.3k). Furthermore, in occasions where ideas were rebutted, and the students negotiated meaning, the students demonstrated that they can be taught how to become critical thinkers instead of accepting ideas and information presented to them passively (Erduran and Jiménez Aleixandre, 2012). When students engage in argumentation, they use and 'then refine their existing knowledge' (Scott Grabinger and Dunlap, 1995, p.19). It can thus be said that this study showed that when the teacher intervenes to invite further and more detailed explanations and challenges the students' ideas, s/he can help the students learn how to be argumentative, developing confidence to test and contest ideas. This indicates that with the implementation of more IBL activities, it might lead to students not only making connections, but in also to discuss alternative procedural methods, challenge their own conclusions, possibly becoming more independent learners (Walker, 2015).

As a result of these findings, it can thus be concluded that in this study, an inquiry-based approach afforded my students the possibility of recontextualising and socially constructing knowledge with and without my interventions (Hmelo-Silver, Duncan and Chinn, 2007; Kirschner, Sweller and Clark, 2006). Taking an inquiry-based learning approach had a positive impact on the students' understanding of the physics concepts that I set out to teach them. This might be difficult to achieve for a teacher working with a whole class (the maximum number of students in a Physics class is seventeen) as it is challenging to support every student's thinking and scaffold each one's learning (Abels, 2015). The use of an IBL approach can promote better understanding of physics concepts. Understanding physics concepts, but being unable to talk and write about them will not make students scientifically literate (Norris and Phillips, 2003). The language used in the classroom thus has a pivotal role in talking science (Tobin and McRobbie, 1996). Language does not only refer to the language of instruction or the students' preferred language when expressing themselves, but also to the language of science (Wellington and Osborne, 2001; Farrell, 1996). For students to talk and write science effectively, they need to also learn and use the specific technical language used in science correctly and cogently (Wellington and Osborne, 2001; Farrell, 1996).

The next section discusses in greater depth the importance of learning and using the language of science and how an inquiry-based approach to learning helped my students to learn and use the technical language of science.

8.4 Learning and using the language of science

While learning of Physics can be enhanced if students are afforded opportunities to work collaboratively and to engage in social construction of knowledge (Abd-El-Khalick, et al., 2004 and Ministry of Education, Employment and the Family, 2012), simply creating an environment where students can engage in “hands-on activities” is often not enough for effective teaching and learning to take place (Fraser et al., 2012). Learning science does not just mean learning to do science (Holbrook and Kolodner, 2000). Learning science implies much more, and involves being able to apply knowledge learned in one context to a different situation (Sawyer, 2008) (e.g. the effect of crumple zones in a car crash in one context and the factors causing an egg to break in another context). This can be achieved when students are provided with opportunities to engage in social interactions (Vincini, 2003), so that they can benefit from the knowledge of those who are more knowledgeable (Hung, 2002) but within Vygotsky’s ‘zone of proximal development’. These social experiences provide learners with authentic experiences. This requires that teachers shift the classroom culture from one involving transmission of knowledge to a learning community where students build knowledge and solve problems by sharing information and experiences within student groups, where students (members of the learning community) learn from each other as well as from the teacher, as they develop personally and academically (Lave and Wenger, 1991).

For students to be scientifically literate, they need to be able to talk and write science (Lemke, 2004). However, it is not enough for students to demonstrate their scientific understanding without necessarily expressing themselves in the appropriate technical jargon (the academic language of science). They are still expected to know the official language of science and also how it is used to talk about science concepts (Lemke, 1990). In Physics, secondary students have to learn several technical terms as part of the Physics repertoire. Many of these terms are not necessarily part of the students’ everyday use, e.g. “momentum”, “impact”, “crumple zone”, “refraction” and “dispersion”, or else have a different meaning. Achieving proficiency in the language of science has been shown to be problematic for many students learning Physics in their first language (Wellington and Osborne, 2001). This research, similar to others (Lodge, 2017; Nyika, 2015;

Miller, 2009; Rollnick, 2000) shows that being able to talk science using the correct ways and expressions can be even more problematic for students learning Physics in their second language. This is mainly due to students having to learn the technical language used in science alongside the second language used for instruction. Students cannot be expected to use technical language correctly, unless they first become familiar with the meaning and use of these technical words (Wellington and Osborne, 2001; Farrell, 1996). Students need to learn these words and expressions. Telling students what they need to know and how to talk about these concepts alhtough a faster way of covering the syllabus, 'telling does not equate learning' (Fisher, Fray and Rothenberg, 2008, p.3).

Techniques which teach the language of science have been examined and have found that learning the language supports 'student learning in STEM' (Hudley and Mallinson, 2017, p.648). Teachers need to teach students the language of science alongside the students' understanding of the subject (Central Advisory Council for Education, 1967). Research has also shown that if the students are not using the language of science, they are not 'developing academic discourse' (ibid., p.3) in their subject area.

Since through inquiry, students talk as they discuss and plan an activity, it creates an opportunity for the students to use and learn the language of science (Huerta and Jackson, 2010). Guided and structured inquiry-based activities are described as teacher-led, not necessarily because the teachers might dominate the classroom talk, but possibly because the questions on a worksheet might be specifically designed to scaffold and direct learning (Hmelo-Silver, Duncan and Chinn, 2007; Kirschner, Sweller and Clark, 2006). However, this does not mean that guided and structured inquiry-based activities restrict the possibilities for students 'to contribute thoughtfully to classroom talk' (Skidmore, 2006, p.507). In an inquiry approach, whether the activity is structured, guided or open, the students need to use talk to understand the task, to discuss and propose ideas, to give explanations, and even to ask questions (Lombard and Schneider, 2013). This study provides further insight about how students can best navigate learning through the use of their first and second language when learning Physics.

The research results particularly showed how allowing my students to talk in their preferred language during the discussions helped them develop their competence in the language of science. In agreement with Huang's (2006), and Barnes' and Todd's (1977) beliefs, this study indicated that word use develops meaning (Vygotsky, 1987). For the students to learn the language of science, they need to be afforded opportunities to use new words and expressions encountered so that with usage and exposure to potential critique from peers and the teacher, over time, these words become part of the students' lexicon. Thus, to demonstrate their scientific understanding the students do not need to only know the technical jargon, but also how to articulate their ideas and explanations clearly. To learn the language of science, the students thus should be encouraged to use technical language during class activities so that they start to make them as their own words and their own ideas (Simon, Erduran and Osborne, 2006). Learning the language of science is a gradual process intertwined with the development of concepts.

This study also showed how, without assessing their ideas and responses, the teacher can support language development by repeating the students' contributions and make sure to use the exact technical language. My students found it useful when I modelled their ideas and responses using the language of science (section 6.7.4), informally connecting the everyday language with the scientific language (Scott, 1998; Yılmaz, 2019). It can be said that this technique helped my students learn and use the language of science appropriately, without the need to continually pinpointing mistakes. Gradually, through this process, the students started to use the language of science correctly during formal parts ofw the activities, such as when presenting their findings and writing down their conclusions to the given activity. For example, during the plenary session of Activity 2 of Cycle Two (Exploring Light through Prisms), the students were able to use the technical words 'refracted', 'reflected' and 'spectrum of white light' correctly to explain the physics concepts which they investigated. The students had already learned these words in the previous lessons while the phrase 'spectrum of white light' was introduced by one of the students himself after the group members used 'rainbow colours'. During Activity 3 of Cycle Two (Egg drop – Land it safely) the students were able to use technical expressions such as 'crumple zone', 'energy', 'speed' and 'impact'. The first word was taught to the students during the engagement stage of the activity while the other three words were taught to them in the previous lessons.

The effectiveness of this technique was substantiated by the students' responses in the semi-structured interview questions as discussed in Chapter 6. This technique worked well with this sample and is an example of how students learn from a more knowledgeable other (Vygotsky) and how students can learn from observing the more knowledgeable member(s) of the community of practice (CoP) and become acquainted with the vocabulary. They then can slowly move from the periphery of the community to fully participating members (Lave and Wenger, 1991). This does not mean that the sample of the students participating in this study would have not learnt and been able to use the technical language had it merely been taught to them by giving them the definitions of the technical words. This study has lead to the use of richer scientific language as well as raised awareness among the students that it was not enough to learn a concept, but to also learn how to talk about it in discussions and explanations.

The role of the teacher in an IBL setting is not limited to the learning of the language of science. The teacher also needs to be capable to provide the needed educational support to promote understanding of concepts (Smart and Marshall, 2013) through an inquiry-based learning approach. Thus, the next section delves into the role of the teacher in an inquiry-based learning setting.

8.5 The role of the teacher in an inquiry-based setting

This study highlighted how the teacher needs to first develop skills for inquiry-based learning activities to be able to organise good inquiry learning opportunities (Engeln, Mikelskis-Seifert and Euler, 2014; Furtak et al., 2012; Towers, 2010; Hmelo-Silver, 2004). The teacher plays a pivotal role in guiding and supporting students to work independently in the learning process (Maaß and Artigue, 2013) in a way that promotes understanding. This study thus has shown how teaching for understanding requires skills in selecting and designing activities, managing small-group work and guiding whole-class discussions (Hmelo-Silver, Duncan and Chinn, 2007). It further demonstrated that the teacher should be able to identify when it is better to refrain from providing answers outright and instead give students space to think, share ideas, discuss, come up with clear arguments, and provide valid explanations (ibid.). The teacher's target is to ensure that the students are scaffolded to construct and 'deliver their own ideas' (Marcum-Dietrich, 2007, p.86).

This study also showed that the teacher needs to scaffold the students' thinking and learning in an IBL approach (Smart and Marshall, 2013; Hmelo-Silver, Duncan and Chinn, 2007) until the students become accustomed to the IBL approach to learning. This can be achieved by presenting the students with a structured or guided inquiry-based activity, as 'important aspects of a task or concept are highlighted' (Hushman and Marley, 2015, p.372). This also shows the importance of the dimensions of time and practice. Over time, the students became accustomed to me and the way that I teach and I became accustomed to how they learn best. Thus, practice likely played a part in the development and deepening of the pedagogic relationships in my classroom: developments in their thinking were likely attributable in part to additional experience with an IBL approach, and in part to enhanced quality of classroom relationship built over time. This highlights the importance of the teacher to build a rapport based on trust where the students are not afraid to express themselves and make mistakes. This study further showed that the using of close-ended neutral non-judgemental questions as well as follow-up questions help the students to build on their responses throughout the discussions, directed their thinking and reflections on the content or context they are engaging with, as well as stimulated further reflections among the students (Huerta and Jackson, 2010). The types of questions posed thus enabled a degree of conceptual understanding to take place (Smart and Marshall, 2013).

This study demonstrated that the role of the teacher in an inquiry-based setting within a bilingual classroom is not limited only to designing the IBL activities or the skilful use of questioning techniques. In a bilingual setting, the teacher has another role, that is, the teacher needs to be sensitive to the impact that the language used during an IBL activity has on the students' ability and willingness to verbalise their scientific knowledge and understanding (Garcia, 2009; Cummins, 2005). This highlights the importance for teachers to explore how best to engage students in more discussions and increase their social construction of knowledge if they are encouraged and allowed to use a language they are comfortable with and which they can use without being self-conscious about their language use and whether they are using the official language of instruction correctly, at least in the process of understanding the new physics concept. In Vygotsky's framework, much of the social learning taking place is mediated by language. Language plays a powerful role in shaping thought and development of appropriate (here, both dialogic and scientific) language, which can become a powerful foundation for complex cognitive skills such as in processing scientific concepts.

8.6 Conclusion on the role of language and an inquiry approach in a bilingual classroom

This study sheds light on the challenges that many students face when learning in their second language/first language but being assessed in their second language. It further shows that in the Maltese classrooms, it does not seem to work well to teach in English if students are struggling with their proficiency in the English language. It also highlighted that allowing students to use their preferred language adds the need for the teacher to explicitly teach the language of physics in a readily-comprehensible language of instruction. This actually is an implication with respect to second language learning.

In the Maltese education system, during Physics lessons, students are expected to ask questions, solve problems, plan and carry out investigations and laboratory experiments, engage in arguments, obtain and discuss the data obtained, explain the physics concepts they are engaging with and draw conclusions (SEC Syllabus, 2023). All this is expected to take place in the English language during official assessment, with English being a second language to many students. The level of Maltese students' proficiency in the English language ranges from a good level (Level B2 on the CFER) to minimal knowledge (somewhere between A2 and B1 on the CFER) of the language. Learners are also expected to use the language of science correctly and to be articulated in their explanations, as well as use proper and enhanced scientific expressions. Hence, students in Malta 'not only must acquire the discursive practice of the scientific field' (Poza, 2018, p.2) which is like a 'foreign culture' (Aikenhead and Jegede, 1999, p.269) to most students in developing and industrialised countries, but to also learn the subject content in their second language. Aikenhead and Jegede (1999) explain that for many students, the transition from talking in a language one is comfortable in (everyday language), to a language which one is uncomfortable with (scientific language), is difficult to achieve. They compare this transition to that of crossing borders from one's home country to a country where the language is totally different; moving from one's comfort zone to a zone which seems 'hazardous' (p.272). Students face a linguistic border-crossing when entering the science classroom; their encounter with the language of science which is different to teir everyday language (even if both are in one language, e.g. English). However, in countries where the classroom language and the language of assessment are different from the students' first language, students are faced with a second border-crossing; that of learning science in a foreign language or in a second language, and one which they are often not used to thinking in.

Evnitskaya (2012) describes learning in a second language like 'a thick glass screen apparently transparent, but impenetrable' (p.1). This applies well to the situation in Maltese classrooms. An investigation carried out by Borg (2010) in Malta indicated that the language used in our classrooms, instead of encouraging co-construction of knowledge between the teacher and the students and/or between the students, was possibly 'one of the principal obstacles' (Evnitskaya, 2012, p.68) for constructing knowledge. Borg (2010) investigated a sample of three hundred and eighty Year 11 students. Year 11 is the final year of compulsory schooling in state, church and independent schools in Malta. This investigation consisted of: i) a questionnaire; ii) a Physics test in the Maltese language and in English language; and iii) an interview on the students' performance in the test. The students demonstrated a preference to be free to answer the questions in Maltese as they were more confident in expressing themselves in their first language. While there is an advantage in allowing students to use their preferred language to express themselves, there is still limited local research on whether the language used in our classrooms is placing any restriction upon the students as they engage in classroom tasks.

The study underpinning this thesis has shown that the Maltese language and the use of code-switching played an important part when students came to articulate their thinking during the IBL activities. The contributions to the discussions were often put forward in the students' first language in the case of Maltese speakers. Maltese and code-switching were used for sophisticated processes, such as when using knowledge, elaborating and demonstrating their reasoning with and without a scientific concept. The language that the students used when they were trying to make sense of the physics phenomena determined their level of participation and consequently knowledge construction. They preferred to use their preferred (and highest proficiency) language when trying to understand what was happening conceptually. This thus demonstrates that the different levels of proficiency in the language in my class was reflected in the language used by the students during the lesson. The more the students spoke in their preferred language, the greater was the amount of their sequences in response to my questions. My contribution as their teacher decreased while the students' initiation of sequences increased significantly in the last activites. This is possibly the result of allowing the students to discuss in their preferred language. The students' choice of language in making sense of physics during the IBL activities appear to have played a crucial role in the learning process. The language the students used seemd to limit/facilitate verbal exchanges depending on their proficiency, highlighting the role that language plays in shaping thought and development of appropriate (here, both dialogic and scientific) language (Vygotsky). Another possibility could be that working within a community of practice, the students learned from the more knowledgeable other and became acquainted with the tasks, and the vocabulary: both aspects appeared to contribute to their learning. This led to a shift in power, possibly as a result of the guidance that I provided to carry out the inquiry-based activities (Mercer, 2008), highlighting that students need to be doing science 'with judicious teacher assistance and support' (Hodson, 2014, p.2547).

As already stated, throughout the lessons carried out as part of Cycle Two, my interventions were intentionally minimal. These interventions served mainly to encourage further consideration by the groups on the questions that they posed as they tried to explain their thoughts, speculate, reason and evaluate. My few contributions removed the teacher's authoritarian figure in dominating discussions. Thus, an inquiry-approach alongside a pedagogy that acknowledges the students' preferred language seems to provide the students with instances to engage in their own learning and communicate 'their evolving understanding in spoken form' (Hardman, 2008, p.132). This study provides insights on how this approach to language use not only has an impact on the students' thinking and content understanding (Hmelo-Silver, Duncan and Chinn, 2007; Kirschner, Sweller and Clark, 2006) but also in their proficiency to talk about scientific ideas. It can be concluded that the use of the students' preferred language in an inquiry setting enabled the students to 'develop linguistically and cognitively' (Hardman, 2008, p.136). Therefore, the findings from this study support the suggestion put forward by Lee and Buxton (2013) that we should create classroom spaces which value as well as encourage the use of different language repertoires.

To summarise, this study has shown that adopting an inquiry-based learning approach which is sensitive to the students' preferred language, has enabled my students to understand the physics concepts better when they were encouraged to talk science, improving also their use of scientific language, as well as become more responsible for their own learning. These findings are consistent with the study carried out by Borg (2010) which showed that allowing students to use their first language makes it easier for the students to express themselves. Though the study underpinning this thesis is limited to one particular group, where the students were faced with three border-crossings, two linguistic and the third border being that of learning Physics through an unfamiliar approach to many, i.e. through an inquiry pedagogical approach, has provided insights which contribute to a gap in knowledge in the Maltese context of learning Physics in secondary schools. Previous research carried out in the Maltese context has focused on the language used by the teachers such as: code-switching (Mifsud, 2012) and translanguaging (Camilleri Grima, 2013) during lesson delivery, and whether students are familiar with polysemous words (Farrell and Ventura, 1998). This study has dug deeper into language use at different points of learning Physics, and how language used by students varied as activities varied from discussions, groupwork to formal presentation of results. The switching from one language to another supported the learning process for second language learners, with first language used mainly when grappling with understanding among students with limited English proficiency, and second language (also the official language of assessment) used in presenting results and preparing writeups for assessment. This research indicates that students probably prefer to think, and to construct knowledge in their first language. They can then learn to express themselves in the formal language of Physics, whether this is in their first or second language.

8.7 How this study supports and refutes the literature

In this study, the students were encouraged to use their preferred language to articulate their understanding of scientific concepts after a number of inquiry-based activities carried out in English showed how language still seemed to impede the students, particularly those students, who were mainly Maltese speaking, from participation and consequently their learning. Msimanga and Lelliot (2014) also put forward the argument that in Southern Africa, when students were encouraged to use their first language, their understanding of concepts was enhanced. However, they further pointed out their concern that the use of home language may place the students 'at a disadvantage as they are denied the chance to practice the English language which they need in order to take examinations' (p.1160). There are however, research studies which show that it is possible to allow students to engage with science concepts in their first language and still enhace their chances of using scientific language (Charamba, 2020a). On the other hand, one also finds researchers who argue that if students engage in their preferred language repertoire, which in this study included a mixture of both English and Maltese in the same contribution, they would struggle when they come to produce the scientific content in their second language in formal assessments (Low, 2016) and this would thus 'counter the productive effects code-switching has on the lessons' (ibid., p.59). Therefore, the literature offers conflicting arguments about the use of the students' preferred language. This calls for further investigation.

The study showed that the contributions put forward by all the students shifted from short phrases to complete sentences (see Tables 4.1, 4.6 and 4.9 for students' contributions in Cycle One and Tables 6.1j, 6.2c and 6.3k for students' contributions in Cycle Two) as they were allowed to speak in any language they preferred. This is in line with the findings by Msimanga and Lelliot (2014) who also noticed instances which demonstrated their students' capability of negotiating meaning among themselves. This study also supports the literature with regards to the students' gains in proficiency in using scientific terminology appropriately (as evidenced in Charamba, 2020a). The findings from this study counters Msimanga and Lelliot's (2014) concern about students' ability to learn how to talk and write about Physics in the official language (English) as my students used acceptable English language during formal assessments such as writing and presentations. Thus, there is a possibility that the use of an inquiry-based approach alongside a pedagogy which encourages students to speak in their preferred language during groupwork, also improved the students' ability and confidence in using English in formal assessments. The interview evidenced how the students became aware that they needed to learn how to express themselves in English when talking and writing about Physics. This study does not provide strong evidence of a causal relationship between adopting an inquiry-based learning approach alongside a pedagogy which encourages the use of different language repertoires and improved ability in demonstrating scientific understanding in a second language. My argument is that with this small sample, the use of IBL alongside allowing the students to express themselves orally in their preferred language had an impact on their teaching and learning as well as improved their proficiency in articulating Physics arguments in English. The findings are promising, however further research is needed to see if these insights obtained would also be effective with a larger sample to see whether it would be effective with different students by taking into consideration different demographics.

An important aspect evident in the literature that I revisited is the role that teacher guidance plays. During this study, my interventions during the exploration stage of the 5E's model, where the students were planning the investigations as well as when they were testing their ideas decreased during Cycle Two. The instances when the students asked for my assistance also decreased. This study thus highlighted that students cannot be expected to know how to carry out inquiry activities and construct knowledge among themselves on their own unless they are provided with appropriate guidance at first. This agrees with Hmelo-Silver, Duncan and Chinn (2007), who advocated the importance of the teacher's guidance before the students become more skilled and more confident to embark on open-inquiry activities, as the role of the teacher becomes less active (Burgh and Nichols, 2012). It was only after the students participated in a number of guided and structured inquiry-based learning activities that my role as the teacher became less direct and took on a more indirect approach to steering the learning process. In fact, there were instances at the beginning where I, as their teacher needed to pose questions to guide their thinking and to invite explanations when they just reported their observations. The outcomes of the analysis show that despite relying less on the teacher's assistance and becoming more responsible for their own learning, the students were still unable to take full responsibility for their own learning. Thus, this study supports the literature on students needing to first do science 'with judicious teacher assistance and support' (Hodson, 2014, p.2547). It also shows that scaffolding is needed before the students can take full responsibility for their own learning and become independent problem-solvers (Hmelo-Silver, Duncan and Chinn, 2007). However, it is possible that I was too keen to guide them to the right outcome and thus was too directive when asking them questions to invite explanations and reflections instead of giving them time to make mistakes.

8.8 Strengths and limitations of this study

This study has shown that taking an inquiry-based learning approach had a positive impact on my students' understanding of the physics concepts. They also improved their ability to talk and write science using the language of science appropriately and cogently (see tables 6.1l, 6.2l, 6.3l and 6.3m). This was particularly the case when, as their teacher, I allowed them to use their preferred language during meaning making. This meant that I had to distribute power in the classroom. It was not enough to just give the students space to think, share their ideas and work at their own pace to carry out the investigation. The significant change in the students' participation was noted when I handed over power to the students by allowing them to decide which language they used during group work. The pedagogic relationships observed deepened as a result of the greater exchanges which took place. This shows how important it is for the teacher to build a rapport based on trust where the students are not afraid to express themselves in a mixture of languages and to make mistakes in their contributions.

This study also highlighted that the amount of scaffolding required by the students in an inquiry approach is temporary, as it decreased over time with practice as suggested by Vygotsky (1978). However, this study does not provide any indication on the quantity or depth of scaffolding students would require before becoming capable to carry out an open-inquiry activity. In fact, this study was carried out over a period of seventeen months, and although there were instances where my intervention as their teacher was minimal, the students still needed support and guidance, despite having questions in the worksheets which were specifically designed to scaffold and guide their learning. It is important to mention that I could have captured only a small subset of relevant data. Although evidencing learning might be more clearly evidenced in a social setting where students are vebalising their thoughts, it is still difficult to evidence who is learning what and in/for what context. For example, certain students might appear quiet, implying that they are less involved or learning less, even if this is not the case, as it is difficult to evidence their learning. Another additional limitation of this study was that more time was required to see whether the students would have been capable to carry out an open-inquiry activity fully on their own. This means that the students would be able to decide the problem, choose the material as well as the approaches required, carry out the inquiry, draw their conclusions and present them. I needed to provide the students with more opportunities to engage in structured and guided IBL activities to structure their learning in a way that would help them gain experience and the skills needed to carry out an open-inquiry activity.

Another limitation to this study was that when the students in this study were in Year 9, I taught two classes. However, the following year I could only teach one of these two classes. This meant that this study was carried out with one class rather than with two. Thus, the findings that emerged from the activities carried out as part of Cycle Two were limited to only one group of students. This sample was a group of the class involving a foreign student who, although understood Maltese, communicated only in English, and four first language Maltese speakers with different levels of proficiency and preference in English. Therefore, I could not compare the findings of this particular group with the findings of the other group from the other class that I had worked with. The second group might have provided better insights for pedagogical implications. Another limitation is that the research design focused on the outcomes of the students (due to time and capacity constraints). I could have also focused on explicitly analysing the changes I adopted, perhaps via a reflective model such as that by Brookfield (1995) as I went through the research project.

One strength in this study was that the four students who participated in the activities carried out during Cycle One also participated in Cycle Two. This made it possible for the analysis of the activities alongside the reflections to guide the next activity with the students. This enabled me to plan each activity according to the students' ability to discuss and share ideas as they make connections between previously acquired knowledge and to construct knowledge and using scientific terminology. Therefore, though this study is limited to a group from one class only, it still provided insights on how to support my students over two scholastic years as I gained insights about their learning challenges: that they needed to be provided with tasks that are challenging but achievable (Willis, 2010); that they needed to be pushed to think deeply by asking open-ended or divergent questions, as they tested their methods and questioned their answers (Hmelo-Silver et al., 2007). In this process, I, as their teacher tried to not be too keen to guide them to the right outcome but give them time to make mistakes and reflect upon them. I adjusted my approach and moved from guided IBL activities (Activity 1 of Cycle One) to structured activities while also allowing the students to use their preferred language (English, Maltese or code-switching) to demonstrate their scientific understanding. This helped with learning the physics concepts I taught them and in developing the linguistic skills to use the language of science cogently.

The main interviews were conducted with three students to whom I had taught Physics as a compulsory subject for two consecutive years (Yuri and Robert) and for one year (Keith) (the year which Cycle Two was carried out). This created both a strength and a limitation to this study. The good relationship between the students and me as their teacher reflected their trust in me, as they felt comfortable to express their views about their experience. One possible limitation of these interviews could be that since I conducted the interviews and the relationship between the students and I could be described as a good relationship and the students were aware that the inquiry-based activities and the interviews were part of the study guiding my PhD thesis, the students could have felt obliged to speak highly of the inquiry-based learning activities, even if they did not really think so highly of these activities. This is possible as the students might have thought that doing so was what I would like to hear, and they wanted to be helpful in facilitating my writing of the thesis.

As a conclusion to this section, this research started off with the premise that the pedagogy I was adopting, and the strict use of the English language, were hindering the students from demonstrating their scientific understanding. The findings of this study have shown that adopting an inquiry-based approach to learning and allowing the students to use their preferred language promoted better understanding of the physics concepts taught as well as enabled the small sample to demonstrate their scientific understanding, mainly through talking about the concepts they were engaging with. It is worth pursuing more research with a larger sample on how a pedagogy that values and encourages the use of different language repertoires in the Maltese classrooms has an impact on learning physics concepts among students whose proficiency in the language of assessment is not as desired. Such research can consider further the relationship between language use and proficiency to science learning and provide policy makers with insights that may potentially assist in the development of forms of science curriculum, particularly Physics, that make the subject more accessible to a wider range of abilities and levels of student language proficiencies. This study did not look at whether adopting an IBL approach which is sensitive to the language used in the classroom has an impact on the students’ performance in formal assessment. Further research on this as well as research on whether setting examinations questions in Maltese and in English and allowing the students to write their answer in either English, Maltese or a mixture of both might also be helpful in obtaining a better picture of the effect that language may have on achievement in Physics (Ventura, 2016).

8.9 Implications for pedagogy

This study has shown that when first language Maltese speakers were allowed to use their preferred language, they used Maltese and code-switching for quite sophisticated processes, such as use of knowledge, elaboration and to demonstrate their reasoning with and without a scientific concept. This means that the language the students are encouraged to use when they are trying to make sense of the physics phenomena can have a major influence on their level of participation. This in turn might lead to a greater possibility for them to engage in the social construction of knowledge, with or without the teacher’s assistance. This might suggest that the teaching of Physics in Malta should be in the language with which the students are familiar, as this helps the development of their understanding of the scientific concepts.

Nowadays, our classrooms are not only bilingual, but are becoming multilingual. One possibility for how our schools can reach students who are neither proficient in the English language, nor proficient in the Maltese language is by providing these students with more practice in one of the two languages and ensuring that these students, have more than ‘enough language knowledge to get by’ before they join mainstream classrooms. Another possibility for how educators can help multilingual students learning Physics (or any other science subject) in Maltese state schools is by including more group work, where students who speak the same language are grouped together. Though some might argue that this will limit their exposure to the English and Maltese languages, and thus, this might limit their opportunities to learn these languages, I argue that because language plays a powerful role in shaping thought (Vygotsky), these students need to first become accustomed to the concept and then, working within a community of practice, where they might learn from the more knowledgeable other and become acquainted with the vocabulary (here both dialogic and scientific) language in order to be able to verbalise their understanding either in English, Maltese or a mixture of both.

Furthermore, since textbooks and exams are in English, policy makers should keep in mind that the English proficiency among secondary students is not as desired. Obviously, the possibility that students in independent schools are given more opportunities to discuss in the science classroom cannot be excluded, especially since this study studied the role of language in an inquiry pedagogy, where discussions are fundamental to such an approach. Such a finding surely sheds light on the fact that this issue of language should be studied and analysed further by policy makers in Malta.

Apart from the possibility of a good level of proficiency in the language of instruction (English) among students attending independent schools, one cannot ignore other factors that play a vital role in students’ performance such as ‘self-efficacy’ (Ministry for Education and Employment, 2015a, p.78) and ‘enjoyment of learning the subject’ (ibid., p.65). Another factor which is related to students’ performance is the economical, social and cultural status (ESCS). The mean ESCS score of students attending independent schools has been found to be significantly higher than that of students attending state schools (ibid.). This thus means, that students attending independent schools also have access to more resources (books, computers, private tutoring) which ‘make it easier for them to succeed in school’ (ibid., p.135). Though the latter cannot be considered as an implication for pedagogy, the issue of language in relation to self-efficacy and enjoyment of learning the subject should be taken into consideration to make Physics more accessible to a wider range of students.

8.10 Implications for policy makers

Ensuring high level student performance in Science is important to Malta at national level (Ministry for Education and Employment, 2014), as science graduates are important to ensure a steady supply of workforce to the labour market and in research, to consequently promote Malta’s further economic growth (Ministry for Education and Employment, 2014). This is a challenge, which the Minister of Education and Employment had identified as a major concern in its educational policy (Ministry for Education and Employment, 2014). Understanding physics concepts but being unable to talk and write about them will not make our students scientifically literate (Norris and Phillips, 2003). Assessment trends highlight the need for better understanding of scientific concepts as well as an improvement in students’ ability to express themselves in English and in using scientific language. Thus, both content knowledge and proficiency in the test language need to be addressed if more students are to engage actively with science.

Since this study showed that the students’ contributions by code-switching were predominant during some activities when compared with the contributions put forward either in English or in Maltese during the same activities, there is a possibility that one activity stimulated fewer contributions than another. Despite this, this study still supports the conclusions drawn by many researchers worldwide: that in a bilingual context, learning science in one’s second language, is an additional hurdle for the students (Msimanga and Lelliott, 2014) and thus, students should be allowed to use their preferred language to verbalise their scientific knowledge and understanding. Therefore, policy makers should encourage teachers to allow more use of the Maltese language and code-switching in their exchanges with peers, especially in classes where the first language of the students is Maltese and they lack proficiency in the English language.

This study also found out that there was an element of translanguaging. Translanguaging was noted when the students replied in Maltese or by code-switching to my questions posed in English and when they replied to contributions put forward in English by the other students. Translanguaging often happens in bilingual and multilingual classrooms as there will be a 'continual shifting from one language to another to satisfy social and pedagogical conditions' (Camilleri Grima, 2016, p.177). This indicates that policy makers should encourage teachers to allow the students to use their preferred language to think aloud, as in this study, this seemed to have facilitated their understanding of physics concepts as well as facilitated the use of scientific language.

In addition, this study has shown that an inquiry-approach alongside a pedagogy that acknowledged the students' preferred language repertoire seems to have provided the students with instances to be engaged as they participated in their own learning and 'communicated their evolving understanding in spoken form' (Hardman, 2008, p.132), and also used scientific language correctly. This study demonstrated that such an approach not only had an impact on their thinking, but also promoted improvement in physics content understanding, which is consistent with several studies (Hmelo-Silver, Duncan and Chinn, 2007; Kirschner, Sweller and Clark, 2006). It is important to highlight that I did not actually measure their performance in Physics - but I could assess it from the students' contributions during the lessons. Thus, it can be concluded that the use of the students' preferred language in an inquiry setting affords an opportunity to the students to 'develop linguistically and cognitively' (Hardman, 2008, p.136). Therefore, policy makers should encourage 'an alternative way of science teaching' (Lodge, 2017, p.661) and also encourage the use of code-switching as a mode of instruction for classroom talk alongside a translanguaging pedagogy, as the use of the students' first language in the science classroom offers a rich means for learning science (Nyika, 2015). However, there should then be an emphasis on teachers to teach the correct use of the English language. This should be made to improve the students' proficiency in the English language, before moving on to discuss science and write science in English. Science teachers also need to be aware that they would have to teach their students how to talk about ideas and express themselves in English.

8.11 Recommendations

This study indicated that the students needed to be guided to engage in an inquiry approach and that the activities needed to be structured at first. This means that students need to first become accustomed to an IBL approach and that they also needed to be scaffolded to be able to construct knowledge with and without the teacher. After the students participated in a number of guided and structured inquiry activities, the role of the teacher in this study became less active and the students were able to construct knowledge among themselves (see table 6.2l). This, is in agreement with Hmelo-Silver, Duncan and Chinn (2007) suggestion, that students need to be provided with appropriate guidance in order for them to learn the skills required to learn through such an approach. Despite the students relying less on the teacher’s assistance and becoming more responsible for their own learning, they were still unable to take full responsibility for the learning. This study supports the literature on students needing to be doing science ‘with judicious teacher assistance and support’ (Hodson, 2014, p.2547) at first, and also shows that a lot of scaffolding is needed before the students can take full responsibility for their learning.

In addition, this study has shown that in an inquiry-based learning approach where the students were encouraged and allowed to use their preferred language repertoire has helped this small sample to express more precise meanings, and even used scientific terms correctly when compared with an inquiry-based learning approach which was not sensitive to the students’ language preference. Following Vygotsky’s insights about the relationship of thought to word, that ‘thought is not expressed but completed in the word’ (Vygotsky, 1978, p.250) and that the teacher's (and more knowledgeable peers') role is in part to scaffold a transition between the current use of language and, here, the physics community's use of the subject-specific lexis, policy makers should, allow ‘an alternative way of science teaching’ (Lodge, 2017, p.661). Such an approach should promote code-switching as a mode of instruction for classroom talk alongside a translanguaging pedagogy, when that supports students’ current levels of linguistic resources. Language plays an important role in enabling the students to develop their ideas in and through language, as the language the students use to each other and to their teacher, enables learning and enables them to verbalise, critique and refine their scientific knowledge. Thus, the use of the students' mother-tongue in the science classroom should be promoted where appropriate as it offers a rich means for learning science (Nyika, 2015) and learning the use the subject-specific lexis. However, an emphasis on correct use of the English language, both everyday and technical, should also be maintained to improve the students' proficiency in the English language, before moving on to discuss science and write science in English, which although an official language in Malta, is more a second language for some. This is a pedagogical imperative, as these students still need to evidence their scientific understanding in English, so that shifts in balance between the languages they are confident to use (Maltese, code-switching, English) are desirable. The balance of productive language use in the classroom requires skilled and sensitive teacher judgement, supporting and challenging students to gradually shift the lexicons with which they are comfortable.

The findings of this study have shown that the use of an IBL approach and a translanguaging pedagogy enabled the small sample to understand the physics concepts I taught them and how to demonstrate their scientific understanding through talk. Taking a social constructivist view of learning, Vygotsky understands this phenomenon as language being productive of thought, and so as directly supporting conceptual development. Since much of my students' learning was gained through interaction with others who are more or differently knowledgeable in some way (peers or teachers), but functioning within their 'zone of proximal development' and so making that learning accessible, which is consistent with Vygotsky's social constructivist theory of learning, this study thus highlighted that more research on how a translanguaging pedagogy and its relation to science learning is needed. A possible research project could be looking at whether there is a causal relationship between adopting an inquiry-based learning approach which is sensitive to the language used in the classroom and the students' performance in formal assessment. It might also be worth investigating whether setting examinations questions in Maltese and in English and allowing the students to write their answer in either English, Maltese or a mixture of both would obtain a better picture of the effect that language also has on achievement in Physics (Ventura, 2016), as students might be able to demonstrate their scientific understanding using everyday language and their preferred language, and thus show that the way formal assessments are set, hinders the possibility of students demonstrating that they are scientifically literate.

After pointing out some changes in pedagogy, it is important to point out that our Maltese language has limited vocabulary in Physics and Science and this issue needs to be addressed first before considering a change. Also learning in Maltese may limit young people's opportunities to continue their studies abroad as they will then have limited English language proficiency. Despite this, at the time being, it would make sense to allow the students to use different languages during class but then the teacher should take on the responsibility of teaching the students the language of science and transition them into it. The study underpinning this thesis has shown that my students were able to achieve this at the end of Cycle Two, and they did improve in demonstrating their scientific knowledge and use the language of science correctly when looking at the contributions they put forward in Cycle One and Cycle Two.

8.12 Concluding comments

This action research was designed to see if the use of inquiry-based learning could help bilingual students in the Maltese context better understand physics concepts. By the end of this research study, the students were able to construct knowledge about physics phenomena they were presented with and even demonstrated better level of understanding of the physics concepts using their preferred language. This is important as it demonstrates that first language Maltese speakers who lack adequate proficiency in the language of assessment (English) can still learn Physics and demonstrate their understanding of the physics concepts as long as the lessons are carefully designed to scaffold their thinking and the teacher is sensitive to the linguistic diversity in the classroom.

This study has shown that when academic spaces that valued and encouraged the use of different language repertories, the students' input during the discussions that took place during the IBL activities implemented, increased. In addition, this study has shown that much of my students' learning was gained through interaction with others who are more or differently knowledgeable in some way (peers or teachers) but functioning within their 'zone of proximal development' and so making that learning accessible, which is consistent with Vygotsky's social constructivist theory of learning. This study thus highlights that policy makers should allow ‘an alternative way of science teaching’ (Lodge, 2017, p.661). Such a way should promote code-switching as a mode of instruction for classroom talk alongside a translanguaging pedagogy, as language plays an important role in enabling the students to develop their ideas in and through language, as the language the students use to each other and to their teacher, enables learning and enables them to verbalise their scientific knowledge. Thus, the use of the students’ mother-tongue in the science classroom should be promoted as it offers a rich means for learning science (Nyika, 2015) especially since classrooms in the Maltese context are becoming more linguistically diverse. Such approaches offer a short-medium term pedagogy that supports confident engagement with, and participation in, physics. It affirms student identity through use of their own linguistic resources and has the potential also to deliberately shift over time to support students in becoming confident users of multiple lexicons (home language, international language such as English, and technical scientific language). They can then come to function effectively in the range of personal, academic and employment contexts in which they need to communicate scientific skills and knowledge.

Supporting the use of different linguistic resources and allowing students to move fluidly between different lexicons allow enhanced access to the speaker or listener’s ZPD. Through interactions with others who are more or differently knowledgeable in some way, but functioning within their zone of proximal development, learning can be more accessible within the community of learners. In Vygotsky's terms, this way of 'scaffolding' the learning, contributes to the strength of the community of learners as it can enable the students to gradually move from a role of 'peripheral participation' in (here) the scientific discipline, to a more central and knowledgeable role.

References

References

Abd-El-Khalick, F., BouJaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D. and Tuan, H.I. (2004). ‘Inquiry in science education: International perspectives’, *Science Education*, 88(3), pp.397-419. doi: 10.1002/sce.10118.

Abels, S. (2015). ‘Scaffolding inquiry-based science and chemistry education in inclusive classrooms’, in Yates, N.L. (ed) *New Developments in Science Education Research*. New York: Nova Science Publishers, pp.77-95.

Adams, A., Jessup, W., Criswell, B. A., Weaver-High, C. and Gregory, T.R. (2015). ‘Using Inquiry To Break the Language Barrier in Chemistry Classrooms’, *Journal of Chemical Education*, 92(12), pp.2062-2066. doi: 10.1021/ed500837p.

Aikenhead, G.S., and Jegede, O.J. (1999). ‘Cross-cultural science education: A cognitive explanation of a cultural phenomenon’, *Journal of Research in Science Teaching*, 36(3), pp.269–287. doi: 10.1002/(SICI)1098-2736(199903)36:3<269::AID-TEA3>3.0.CO;2-T.

Aina, J. K. (2017). ‘Developing a Constructivist Model for Effective Physics Learning’, *International Journal of Trend in Scientific Research and Development*, 1(4), pp.59-67.

Ainley. M. and Ainley, J. (2011). ‘Student engagement with science in early adolescence: The contribution of enjoyment to students’ continuing interest in learning about science’, *Contemporary Educational Psychology*, 36(1), pp.4-12. doi: 10.1016/j.cedpsych.2010.08.001.

Akınoğlu, O. and Ozkardes Tandoğan, R. (2007). ‘The effects of Problem-Based Active Learning in Science Education on Students’ Academic Achievement, Attitude and Concept Learning’, *Eurasia Journal of Mathematics, Science and Technology Education*, 3(1), pp.71-81. doi: 10.12973/ejmste/75375.

Alfieri, L., Brooks, P., Aldrich, N. and Tenenbaum, H. (2011). ‘Does discovery-based instruction enhance learning?’, *Journal of Educational Psychology,* 103(1), pp.1-18. doi: 10.1037/a0021017.

Alozie, N.M., Moje, E.B. and Krajcik, J.S. (2010). ‘An analysis of the supports and constraints for scientific discussion in high school project-based science', *Science Education*, 94(3), pp.395-427. doi: 10.1002/sce.20365.

Anand, P.G. and Ross, S.M. (1987). 'Using computer-assisted instruction to personalise arithmetic materials for elementary school children', *Journal of Educational Psychology*, 79(1), pp.72-78. doi: 10.1037/0022-0663.79.1.72.

Anderman, E.M. and Anderman, L.H. (2010). *Classroom motivation*. Boston, MA: Pearson.

Anderson, R.D. (2002). 'Reforming Science Teaching: What research says about inquiry', *Journal of Science Teacher Education,* 13(1), pp.1-12. doi: 10.1023/A:1015171124982.

Arons, A.B. (1983). 'Achieving wider scientific literacy', *Deadalus*, 112(2), pp.91 – 122.

Askew, M., Brown, M., Rhodes, V., Johnson, D. and William, D. (1997). *Effective Teachers of Numeracy, Final Report*. London: King's College.

Ausubel, D.P., (1963). *The psychology of meaningful verbal learning*. New York: Grune & Stratton.

Ausubel, D.P. (1968). *Educational Psychology: A Cognitive View*. New York and Toronto: Holt, Rinehart and Winston.

Baker, C. (2019). 'A tribute to Ofelia García', *Journal of Multilingual Education Research*, 9(8), pp.175-182.

Baker, C. (2011). *Foundations of bilingual education and bilingualism* (5th ed.). Bristol: Multilingual Matters.

Baker, C. (2000). *The care and education of young bilinguals*. *An Introduction for Professionals*. Clevedon: Multilingual Matters.

Barnes, D. and Todd, F. (1977). *Communication and Learning in Small Groups*. Abingdon: Routledge and Kegan Paul.

Barrow, L.H. (2006). 'A Brief History of Inquiry: From Dewey to Standards', *Journal of Science Teacher Education*, 17(3), pp.265-278. doi: 10.1007/s10972-006-9008-5.

Berland, L.K. and Reiser, B.J. (2009). 'Making Sense of Argumentation and Explanation', *Science Education*, 93(1), pp.26-55. doi: 10.1002/sce.20286.

Berman, J. (2013). Utility of a Conceptual Framework within Doctoral Study: A Researcher's Reflections. Issues in Educational Research, 23 (1), 1-18.

Bergman, D. (2013). 'Blending Language Learning with Science', *The Science Teacher*, 80(4), pp.46-50.

Bevins, S. and Gareth Price, G. (2016). 'Reconceptualising inquiry in science education', *International Journal of Science Education*, 38(1), pp.17-29. doi: 10.1080/09500693.2015.1124300.

Bhattacherjee, A. (2012). Social Science Research: Principles, Methods, and Practices. Textbooks Collection. 3. [Online]. Available at: http://scholarcommons.usf.edu/oa_textbooks/3.

Blanchard, B., Masserot, V. and Holbrook, J. (2014). 'The PROFILES Project Promoting Science Teaching in a Foreign Language', *Science Education International,* 25(2), pp.78-96.

Borg, E. (2010). *Language use in Physics education at SEC Level*. Unpublished M.Ed. dissertation. University of Malta.

Braun, V. and Clarke, V. (2006). 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, 3(2), pp.77–101. doi: 10.1191/1478088706qp063oa.

Brookfield, S. (1995). *Becoming a Critically Reflective Teacher*. San-Francisco: Jossey-Bass.

Brown, P.L. and Concannon, J.P. (2016). 'Students' perceptions of vocabulary knowledge and learning in a middle school science classroom', *International*

Journal of Science Education, 38(3), pp.391-408. doi: 10.1080/09500693.2016.1143571.

Bulunuz, M., Jarrett, O.S. and Martin-Hansen, L. (2012). 'Level of Inquiry as Motivator in an Inquiry Methods Course for Pre-service Elementary Teachers', *School Science and Mathematics*, 112(6), pp.330-339. doi: 10.1111/j.1949-8594.2012.00153.x.

Burgh, G. and Nichols, K. (2012). 'The Parallels Between Philosophical Inquiry and Scientific Inquiry: Implications for science education', *Educational Philosophy and Theory*, 44(10), pp.1045-1059. doi: 10.1111/j.1469-5812.2011.00751.x.

Burns, A. (2015). 'Action Research', in Brown, J.D. and Coombie, C. (eds.) *The Cambridge Guide to Research in language Teaching and Learning* (1st Edition). Cambridge: Cambridge University Press, pp.99-104.

Burton, (2023). *What are Learning Communities? (Examples, Types and Best Practices).* [Online]. Available at: https://www.thinkific.com/blog/what-is-a-learning-community/ Accessed: 15 May 2023).

Bybee, R.W., Taylor, J.A., Gardner, A., Van Scotter, P., Powell, J.C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs, CO: BSCS.

Bybee, R. W. (2002). 'Scientific inquiry, student learning, and the science curriculum', in Bybee, R.W. (ed.) *Learning science and the science of learning*. USA: NSTA Press, pp.25-35.

Cakir, M. (2008). 'Constructivist approaches to learning in science and their implication for science pedagogy: A literature review', *International Journal of Environmental and Science Education*, 3(4), pp.193-206.

Camilleri Grima, A. (2016). 'Bilingualism in education in Malta [Editorial]', *Malta Review of Educational Research*, 10(2), pp.177-179.

Camilleri Grima, A. (2013). 'A select review of bilingualism in education in Malta', *International Journal of Bilingual Education and Bilingualism*, 16(5), pp.553-569. doi: 10.1080/13670050.2012.716813.

Carlsen, W.S. (2013). ‘Language and science learning’, in Abell, S.K. and Lederman, S.G. (eds) *Handbook of research on science education*. Routledge, pp. 57-74.

Carre' C. (1981). *Language Teaching and Learning: Science*. London: Ward Lock.

Cenoz, J. and Gorter, D. (2020). ‘Pedagogical Transclanguaging: An Introduction’, *An International Journal of Educational Technology and Applied Linguistics*, 92, pp.1-6. doi: 10.1016/j.system.2020.102269.

Central Advisory Council for Education. (1967). *The Plowden Report, Children and their Primary Schools*. London: HMSO. [Online]. Available at: https://en.wikipedia.org/wiki/Plowder_Report (Accessed: 20 April 2020).

Charamba, E. (2021). ‘Learning and language: towards a reconceptualization of their mutual interdependences in a multilingual science class’, *Journal of Multilingual and Multicultural Development*, 42(6), pp.503-521. doi: 10.1080/01434632.2019.1707837.

Charamba, E. (2020a). ‘Translanguaging in a multilingual class: a study of the relation between students’ languages and epistemological access in science’, *International Journal of Science Education*, 42(11), pp.1779-1798. doi: 10.1080/09500693.2020.1783019.

Charamba, E. (2020b). ‘Translanguaging: developing scientific scholarship in a multilingual classroom’, *Journal of Multilingual and Multicultural Development*, 41(8), pp.655-672. doi: 10.1080/01434632.2019.1625907.

Cassels, J.R.T. and Johnstone, A.H. (1985). *Words That Matter in Science.* London: Royal Society of Chemistry.

Chin, C. (2006). ‘Classroom interaction in science: Teacher questioning and feedback to students’ responses’, *International Journal of Science Education*, 28(11), pp.13-15. doi: 10.1080/09500690600621100.

Clarke, V. and Braun, V. (2013). 'Teaching thematic analysis: Over- coming challenges and developing strategies for effective learning', *The Psychologist*, 26(2), pp.120-123.

Cohen, L., Manion, L. and Morrison, K. (2011). *Research Methods in Education* (7th Edition). London: Routeledge.

Colburn, A. and Nguyen, H.T. (2012). 'Every Word You Speak: Helping English Language Learners Swim in the Science Language Stream', *The Science Teacher*, 79(4), pp.58-61.

Colburn, A.I. (2000). 'An Inquiry Primer', *Science Scope*, 23(6), pp 42-44.

COMPASS. (2009). *Common Problem Solving Strategies as Links between Mathematics and Science*. [Online]. Available at: http://www.compass- project.eu (Accessed: 15 May 2015).

Constitution of Malta (1964). Available at: LEĠIŻLAZZJONI MALTA (legislation.mt) (Accessed: 20 June 2020).

Conteh, J. (2018). 'Translanguaging', ELT Journal, 72(4), pp. 445-447. doi: 10.1093/elt/ccy034.

Common European Framework of Reference for Language (2020). Available at: https://www.coe.int/en/web/common-european-framework-reference-languages/leveldescriptions#:~:text=The%20CEFR%20organises%20language%20proficiency,'can%2Ddo'%20descriptors (Accessed: 20 June 2022).

Costa, M. (2018). 'Lack of science education keeping Maltese children behind', MaltaToday, 20 November. Available at: https://www.maltatoday.com.mt/news/national/91061/lack_of_science_education_keeping_maltese_children_behind#.XcqVNq2ZP-b (Accessed: 5 January 2019).

Coultas, V. (2012). 'Classroom Talk are we listening to teachers̓ voices', *English in Education*, 46(2), pp.175–189. doi: 10.1111/j.1754-8845.2012.01125.x

Costello, P.M. (2011). 'Why Undertake Action Research?', in P.M. Costello *Effective Action Research*, London: Continuum.

Crawford, B.A. (2000). ‘Embracing the essence of inquiry: New roles for science teachers’, *Journal of Research in Science Teaching*, 37(9), pp.916-937. doi: 10.1002/1098-2736(200011)37:93.3.CO;2-U.

Creese, A., and Blackledge, A. (2010). ‘Translanguaging in the Bilingual Classroom: A Pedagogy for Learning and Teaching’, T*he Modern Language Journal*, 94(1), pp.103-115. doi: 10.1111/j.1540-4781.2009.00986.x.

Cummins, J. (2008). ‘BICS and CALP: Empirical and theoretical status of the distinction’, in Street, B. and Hornberger, N.H. (eds.) *Encyclopedia of language and education*. New York: Springer Science and Business Media LLC, pp.71-83.

Cummins, J. (2005). ‘A Proposal for Action: Strategies for Recognizing Heritage Language Competence as a Learning Resource Within the Mainstream Classroom’, *The Modern Language Journal*, 89(4), pp.585-592.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B. and Osher, D. (2020). ‘Implications for educational practice of the science of learning and development’, *Applied Developmental Science*, 24(2), pp.97-140. doi: 10.1080/10888691.2018.1537791.

Darsih, E. (2018). ‘Learner-centered teaching: What makes it effective’. *Indonesian EFL Journal*, *4*(1), pp.33-42. doi: 10.25134/ieflj.v4i1.796.

Deguara, J. (2009). *Towards developing an early years curriculum framework for the Maltese context*. Unpublished M.Ed dissertation. University of Malta.

Delpit, L. (1995). *Other people’s children: Cultural conflict in the classroom*. New York: New Press.

Denzin, N.K. and Lincoln, Y.S. (2005). ‘Introduction: The discipline and practice of qualitative research’ in Denzin, N.K. and Lincoln, Y.S. (eds.) *The SAGE handbook of qualitative research* (3rd ed.). California: Sage Publications, Thousand Oaks, pp.1-32.

Devetak, I., Glazar, S.A. and Vogrinc, J. (2010). ‘The Role of Qualitative Research in Science Education’, *Eurasia Journal of Mathematics, Science and Technology Education,* 6(1) pp.77-84. doi: 10.12973/ejmste/75229.

Dewey, J. (1925). *Experience and Nature*. New York: Dover Publications Inc.

Dewey, J. (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. Boston, MA: D.C. Heath and Co Publishers.

Duran, L. B., and Duran, E. (2004). ‘The 5E instructional model: A learning cycle approach for inquiry-based science teaching’, *Science Education Review*, *3*(2), pp.49-58.

Duschl, R.A., and Osborne, J. (2002). ‘Supporting and Promoting Argumentation Discourse in Science Education’, *Studies in Science Education,* 38(1), pp.39-72. doi: 10.1080/03057260208560187.

Edwards, D. (2005). ‘Discursive Psychology’, in Fitch, K.L. and Sanders, R.E. (eds.) *Handbook of Language and Social Interaction.* Mahwah, NJ: Lawrence Erlbaum, pp.257-273.

Elbardan, H. and Kholeif, A.O.R. (2017). ‘An interpretative Approach for Data Collection and Analysis’, in Elbardan, H. and Kholeif, A. (eds.) *Enterprise Resource Planning, Corporate Governance and Internal Auditing*. Cham: Palgrave Macmillan, pp.111-165.

Engeln, K., Mikelskis-Seifert, S. and Euler, M. (2014). ‘Inquiry-based Mathematics and Science Education across Europe: A synopsis of various approaches and their potentials’, in Bruguière, C., Tiberghein, A. and Clément, P. (eds.) *Topics and Trends in Current Science Education*. Netherlands: Springer, pp.229-242.

Enghag, M., Gustafsson, P. and Jonsson, G. (2007). ‘From Everyday Life Experiences to Physics Understanding Occurring in Small Group Work with Context Rich Problems During Introductory Physics Work at University’, *Research in Science Education*, 37, pp.449-467. doi: 10.1007/s11165-006-9035-4.

Erduran, S. and Jiménez Aleixandre, M.P. (2012). ‘Argumentation in Science Education Research’, in Jorde, D. and Dillon, J. (eds) *Science Education Research and Practice in Europe. Cultural Perspectives in Science Education*, vol 5. Rotterdam: Sense Publishers, pp.253-289.

Eun, B. (2019). ‘The zone of proximal development as an overarching concept: A framework for synthesizing Vygotsky’s theories’, *Educational Philosophy and Theory*, 51(1), pp.18-30. doi: 10.1080/00131857.2017.1421941.

Evnitskaya, N. (2012). *Talking science in a second language. The interactional co-construction of dialogic explanations in the CLIL science classroom*. Ph.D. Thesis. Universitat Autònoma de Barcelona. Available at: https://www.academia.edu/2258677/Talking_science (Accessed: 20 February 2021).

Fang, Z., Lamme, L. L., and Pringle, R. M. (2010). *Language and literacy in inquiry-based science classrooms, grades 3-8*. California: Corwin Press.

Farrell, M. (1996). *English in Physics: The influence of English language proficiency on Maltese students' attainment in physics at advanced level.* Unpublished M.Ed dissertation. University of Malta.

Farrell, M. and Ventura, F. (1998). ‘Words and understanding in Physics’, *Language and Education*, 12(4), pp.243-253. doi: 10.1080/09500789808666752.

Farrell, M. (2011). ‘Bilingual competence and students' achievement in Physics and Mathematics’, *International Journal of Bilingual Education and Bilingualism*, 14(3), pp.335-345. doi: 10.1080/13670050.2010.516817.

Farrugia, M.T., Muscat, D., Casha Sammut, M. and Vella, L.A. (2022). *A bilingual glossary of Mathematics terms – the early and junior years*. Malta: Outlook Coop.

Farrugia, M.T. (2009a). ‘Registers for mathematics classrooms in Malta: Considering options’. *For the Learning of Mathematics*, 29(1), pp.20-25.

Farrugia, M.T. (2009b). ‘Reflections on a medium of instruction policy for mathematics in Malta’, in Barwell, R. (ed.) *Multilingualism in mathematics classrooms.* Bristol: Multilingual Matters, pp.97-112.

Feldman, A., and Minstrell, J. (2000). *Action research as a research methodology for the study of the teaching and learning of science*. ERIC Clearinghouse.

Ferguson, G. (2006). *Language planning and education*. Edinburgh, Scotland: Edinburgh University Press.

Ferguson, G. (2003). ‘Classroom code-switching in post-colonial contexts: Functions, attitudes and policies’, *AILA Review*, 16(1), pp.38-51. doi: 10.1075/aila.16.05fer.

Feser, M.S. and Höttecke, D. (2021). ‘Exploring the Role of Language in Physics Teachers’ Everyday Assessment Practice’, *Journal of Science Teacher Education*, 32(6), pp.686-704. doi: 10.1080/1046560X.2021.1890926.

Fibonacci. (2012). *Disseminating Inquiry-based Science and Mathematics Education in Europe*. [Online]. Available at: http://www.fibonacci- project.eu/ (Accessed :1 June 2015).

Fisher, D., Frey, N. and Rothenberg, C. (2008). *Content-Area Conversations*. Virginia: Association for Supervision and Curriculum Development.

Foster, C. (2014). ‘Minimal interventions in the teaching of mathematics’, *European Journal of Science and Mathematics Education,* 2(3), pp.147-154. doi: 10.30935/scimath/9407.

Fraser, B.J. (2012). ‘Classroom Learning Environments: Retrospect, Context And Prospect’, in Fraser, B.J., Tobin, K.G. and McRobbie, C.J., (eds.) *The Second International Handbook of Science Education*. Springer: Dordrecht: pp.1191-1239.

Frendo, H. (1975). ‘Language and nationality in an island colony: Malta’. *Canadian Review of Studies in Nationalism*, 3, pp.22-33.

Frendo, R. (2018). *Bilingualism in Grade V Maltese Primary Schools A Sociolinguistic Perspective*. Ph.D. Thesis. University of Malta. Available at: 18PHD english.pdf (Accessed: 24 June 2021).

Furtak, E.M., Seidel, T., Iverson, H. and Briggs, D.C. (2012). ‘Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching: A Meta-Analysis’, *Review of Educational Research*, 12(3), pp.300-329. doi: 10.3102/0034654312457206.

García, O. (2014). ‘Countering the dual: Transglossia, dynamic bilingualism, and translanguaging in education’, in R. R. L. Alsagoff, R.R.L. (ed.) *The global-local interface, language choice and hybridity*. Bristol, UK: Multilingual Matters, pp.100-118.

Garcia, O., and Wei, L. (2014). *Translanguaging: Language, Bilingualism and Education*. London: Palgrave Pivot.

García, O. (2009). *Bilingual Education in the 21st Century: A Global Perspective*. West Sussex: Wiley Blackwell.

Garza, E. and Arreguín-Anderson, M.G. (2018). ‘Translanguaging: Developing scientific inquiry in a dual language classroom’, *Bilingual Research Journal*, 41(2), pp.101-116. doi: 10.1080/15235882.2018.1451790.

Gatt, S. (2005). ‘Promoting the Construction of Knowledge during practical work’, in Costa, M.F., Dorrío, B.V., Michaelides, P. and Divjak, S. (eds) *Selected Papers on Hands-on Science, pp.* 100-128.

Gauci, H. and Camilleri Grima, A. (2012). ‘Codeswitching as a tool in teaching Italian in Malta’, *International Journal of Bilingual Education and Bilingualism*, 16(5), pp.615-631. doi: 10.1080/13670050.2012.716817.

Gillies, R.M. and Khan, A. (2008). ‘The effects of teacher discourse on students’ discourse, problem-solving and reasoning during cooperative learning’, *International Journal of Educational Research*, 47(6), pp.323-340. doi: 10.1016/j.ijer.2008.06.001.

Goodchild, S., Fuglestad, A.B. and Jaworski, B. (2013). ‘Critical alignment in inquiry-based practice in developing mathematics teaching’, *Educational Studies in Mathematics,* 84(3), pp.393-412. doi: 10.1007/s10649-013-9489-z.

Gort, M. (2015). ‘Transforming Literacy Learning and Teaching Through Translanguaging and Other Typical Practices Associated with “Doing Being Bilingual”’, *International Multilingual Research Journal*, 9(1), pp.1–6. doi: 10.1080/19313152.2014.988030.

Guba, EG. and Lincoln, Y.S., (1994). ‘Competing paradigms in qualitative research’, in Denzin, N.K. and Lincoln, Y.S. (eds.), *Handbook of qualitative research*. California: Thousand Oaks, Sage Publications pp.105–117.

Halim, L., Dahlan, F. and Treagust, D.F. (2012). 'Experiences of teaching the heat energy topic in English as a second language', *Science Education International*, 23(2) pp.117-132.

Hand, B., Yore, L.D., Jagger, S. & Prain, V. (2010). Connecting research in science literacy and classroom pratice: a review of science teaching journals in Australia, the UK and the United States, 1998-2008, *Studies in Science Education*, 46(1), pp.45-68. doi: 10.1080/03057260903562342.

Hardman, F. (2008). 'Teachers' Use of Feedback in Whole-class and Group-based Talk', in Mercer, N. and Hodgkinson, S. (eds.) *Exploring talk in school*. California: Sage Publication, Thousand Oaks, pp.131-150.

Harlow, D. and Otero, V. (2006). 'Talking to Learn Physics and Learning to Talk Physics', *Physics Education Research Conference Proceedings*, 18(1), pp.53-56. doi: 10.1063/1.2177021.

Harris, C., and Rooks, D. (2010). 'Managing inquiry-based science: challenges in enacting complex science instruction in elementary and middle school classrooms', *Journal of Science Teacher Education*, 21(2), pp.227-240. doi: 10.1007/s10972-009-9172-5.

Hawkins, B.S.R. (1990). *The management of staff development in a contracting education service*. Unpublished Ph.D. thesis. Birmingham Polytechnic.

Heller, M. (1999). *Linguistic Minorities and Modernity: A Sociolinguistic Ethnography*. London: Longman.

Henry, D.L., Nistor, N. and Baltes, B. (2014). 'Examining the Relationship Between Math Scores and English Language Proficiency', *Journal of Educational Research and Practice*, 4(1), pp.11-29. doi: 10.5590/JERAP.2014.04.1.02.

Heitmann, P., Hecht, M., Schwanewedel, J. and Schipolowski, S. (2014). 'Students' Argumentative Writing Skills in Science and First-Language Education: Commonalities and differences', *International Journal of Science Education*, 36(18), pp.3148-3170. doi: 10.1080/09500693.2014.962644.

Hensen, K. T. (1996). ‘Teachers as researchers’, on Sikula, J. (ed.) *Handbook of research on teacher education* (4th Edition). New York: Macmillan, pp. 53-66.

Herr, K. and Anderson, G.L. (2015). *The action research dissertation. A guide for students and faculty*. USA: Sage Publications.

Herrlitz-Biró, L., Elbers, E. and De Haan, M. (2013). ‘Key words and the analysis of exploratory talk’, *European Journal of Psychology of Education*, 28(4), pp.1397-1415. doi: 10.1007/s10212-013-0172-7.

Heugh, K. (2015). ‘Epistemologies in Multilingual Education: Translanguaging and Genre—Companions in Conversation with Policy and Practice’, *Language and Education*, 29(3), pp.280-285. doi: 10.1080/09500782.2014.994529.

Hine, G.S. (2013). ‘The importance of action research in teacher education programs’, *Issues in Educational Research*, 23(2), pp. 151-163.

Hmelo-Silver, C.E. (2004). ‘Problem-based learning: What and how students learn?’, *Educational Psychology Review,* 16(3), pp.235-266. doi: 10.1023/B:EDPR.0000034022.16470.f3.

Hmelo-Silver, C.E., Duncan, R.G. and Chinn, C.A. (2007). ‘Scaffolding and Achievement in Problem-Based and Inquiry Learning: A response to Kirschner, Sweller, and Clark (2006)’, *Educational Psychologist,* 42(2), pp.99-107. doi: 10.1080/00461520701263368.

Hodson, D. (2014). ‘Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods’, *International Journal of Science Education*, 36(15), pp.2534-2553. doi: 10.1080/09500693.2014.899722.

Hogan, K., Nastasi, B. and Pressley, M. (2000). ‘Discourse patterns and collaborative scientific reasoning in peer and teacher-guided discussions’, *Cognition and Instruction*, 17(4), pp.379-432. doi: 10.1207/S1532690XCI1704_2.

Holbrook, J. and Kolodner, J.L. (2000). ‘Scaffolding the Development of an Inquiry-Based (Science) Classroom’, in Fishman, B. and O'Connor-Divelbiss, S. (eds.) *Fourth International Conference of the Learning Sciences*. Mahwah, NJ: Lawrence Erlbaum.

Hossain, M. and Robinson, M.G. (2012). ‘How to Motivate U.S. Students to Pursue STEM (Science, Technology, Engineering and Mathematics) Careers’, *US-China Education Review* A., (4), pp.442-451.

Howe, K. R. (1998). ‘The interpretive turn and the new debate in education’, *Educational Researcher*, *27*(8), pp.13-20. doi: 10.3102/0013189X027008013.

Huang, H. (2006). ‘Listening to the language of constructing science knowledge’, *International Journal of Science and Mathematical Education*, 5(4), pp.391-415. doi: 10.1007/s10763-005-9010-y.

Hudley, A. H. and Mallinson, C. (2017). ‘It’s Worth Our Time: A Model of Culturally and Linguistically Supportive Professional Development for K-12 STEM Education’, *Cultural Studies of Science Education*, 12(3), pp.637-660. doi: 10.1007/s11422-016-9743-7.

Huerta, M. and Jackson, J. (2010). ‘Connecting Literacy and Science to Increase Achievement for English Language Learners’, *Early Childhood Education Journal*, 38(3), pp.205-211. doi: 10.1007/s10643-010-0402-4.

Hurd, P.D. (1958). ‘Science Literacy: Its Meaning for American schools’, *Educational Leadership*, 16(1), pp.13-16.

Hushman, C.J. and Marley, S.C. (2015). ‘Guided Instruction Improves Elementary Student Learning and Self-Efficacy in Science’, *The Journal of Educational Research*, 108(5), pp.371-381. doi: 10.1080/00220671.2014.899958.

Infante, P. and Licona, P.R. (2021). ‘Translanguaging as pedagogy: developing learner scientific discursive practices in a bilingual middle school science classroom’, *International Journal of Bilingual Education and Bilingualism*, 24(7), pp.913-926. doi: 10.1080/13670050.2018.1526885.

International Organization for Migration. (2015). Migration in Malta: Country Profile. Avalable at: https://publications.iom.int/system/files/pdf/mp_malta_13july2016_0.pdf (Accessed: 22 August 2016).

Johnson, A.P. (2012). *A short Guide to Action Research* (4th Edition). New York City, New York: Pearson.

Kahle, J.B., Meece, J. and Scantlebury, K. (2000). ‘Urban African- American middle school science students: Does standards-based teaching make a difference?’, *Journal of Research in Science Teaching*, 37(9), pp.1019-1041. doi: 10.1002/1098-2736(200011)37:9<1019::AID-TEA9>3.0.CO;2-J.

Karlsson, A., Larsson, P.N. and Jakobsson, A. (2019). ‘Multilingual students’ use of translanguaging in science classrooms’, *International Journal of Science Education*, 41(15), pp.2049-2069. doi: 10.1080/09500693.2018.1477261.

Kieffer, M.J., Lesaux, N.K., Rivera, M., & Francis, D.J. (2009). ‘Accommodations for English language learners taking large scale assessments: A meta-analysis on effectiveness and validity’, *Review of Educational Research*, 79(3), pp.1168-1202. doi: 10.3102/0034654309332490.

Kirch, S.A. (2010). ‘Identifying and resolving uncertainty as a mediated action in science: A comparative analysis of the cultural tools used by scientists and elementary science students at work’, *Science Education*, 94(2), pp.308-335. doi: 10.1002/sce.20362.

Kirschner, P.A., Sweller, J. and Clark, R.E. (2006). ‘Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching’, *Educational Psychologist*, 41(2), pp.75-86. doi: 10.1207/s15326985ep4102_1.

Kolb, D.A. (1984). ‘Experiential Learning’. Available at: http://www.learning-theories.com/experiential-learning-kolb.html (Accessed: 16 June 2016).

Koshy, E., Koshy, V. and Waerman, H. (2011). *Action Research in Healthcare*. California: Thousand Oaks, Sage Publication.

Krajcik, J. S., and Czerniak, C. M. (2018). *Teaching science in elementary and middle school: A project-based learning approach*. New York: Routledge.

Kriewaldt, J., Robertson, L., Ziebell, N., Di Biase, R. and Clarke, D. (2021). ‘Examining the nature of teacher interactions in a collaborative inquiry-based classroom setting using a Kikan-Shido lens', *International Journal of Educational Research*, 108, pp.1-13. doi: 10.1016/j.ijer.2021.101776.

Lambirth, A. (2009). 'Ground rules for talk: the acceptable face of prescription', *The Curriculum Journal*, 20(4), pp.423-435. doi: 10.1080/09585170903424971.

Larrain, A., Freire, P., Strasser, K. and Grau, V. (2020). 'The development of a coding scheme to analyse argumentative utterances during group-work', *Thinking Skills and Creativity*, 36, 100657. doi: 10.1016/j.tsc.2020.100657.

Larrain, A., Howe, C. and Cerda, J. (2014). 'Argumentation in Whole-Class Teaching and Science Learning', *PSYKHE*, 23(2), pp.1-15. doi: 10.7764/psykhe.23.2.712.

Lave, J. and Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation (Learning in Doing: Social, Cognitive and Computational Perspectives*. Cambrdge: Cambridge University Press.

Lee, O. and Buxton, C.A. (2013). 'Integrating Science And English Proficiency For English Language Learners', *Theory Into Practice*, 52(1), pp.36-42. doi:10.1080/07351690.2013.743772.

Lee, O., Quinn, H., and Valdés, G. (2013). 'Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English Language Arts and Mathematics', *Educational Researcher*, 42(4), pp.223–233. doi: 10.3102/0013189X13480524.

Lemke, J.L. (2004). 'The literacies of science', in Saul, W. (ed) *Crossing borders in literacy and science instruction: Perspectives on theory and practice*. Newark, DE : International Reading Association, pp.33-47.

Lemke, J.L. (1990). *Talking science: language, learning and values* Westport, CT: Ablex.

Lewis, G., Jones, B. and Baker, C. (2013). '100 bilingual lessons: Distributing two languages in classrooms' in Abello-Contesse, C., Chandler, P. M., López-Jiménez, M.D. and Chacón-Beltrán, R. (eds.) *Bilingual and Multilingual Education* *in the 21st Century: Building on Experience*. Bristol, Blue Ridge Summit: Multilingual Matters, pp.107-135.

Lodge, W. (2017). 'Science learning and teaching in a Creole-speaking environment'. *Cultural Studies of Science Education,* 12(3), pp.661–675. doi: 10.1007/s11422-016-9760-6.

Lombard, F.E. and Schneider, D.K. (2013). 'Good student questions in inquiry learning', *Journal of Biological Education*, 47(3), pp.166-174. doi: 10.1080/00219266.2013.821749.

Low, S.M. (2016). *The Effectiveness of Classroom Code-switching in Malaysian Science Classrooms*. Ph.D. Thesis. University of Sheffield. Available at: 77022934.pdf (core.ac.uk) (Accessed: 22 June 2022).

Maaß, K. and Artigue, M. (2013). 'Implementation of inquiry-based learning in day- to-day teaching: A synthesis', *ZDM: the international journal on mathematics education,* 45(6), pp.779-795. doi: 10.1007/s11858-013-0528-0.

Machemer, P.L. and Crawford, P. (2007). 'Student Perceptions of Active Learning in a Large Cross-Disciplinary Classroom', *Active Learning in Higher Education*, 8(1), pp.9-30. doi: 10.1177/1469787407074008.

MacLellan, E. and Soden, R. (2004). 'The Importance of Epistemic Cognition in Student-Centred Learning', *Instructional Science*, 32(3), pp.253-268. doi: 10.1023/B:TRUC.0000024213.03972.ce.

MacSwan, J. (2017). 'A Multilingual Perspective on Translanguaging', *American Educational Research Journal*, 54(1), pp.167–201. doi: 10.3102/0002831216683935.

Maguire, M. And Delahunt, B. (2017). 'Doing a Thematic Analysis. A practical step-by-step guide for Learning and Teaching Scholars'. *All Ireland Journal of Teaching and Learning in Higher Education*, 8 (3), p.3351-33514.

Marcum-Dietrich, N.I. (2007). 'Using Constructivist Theories to Educate the "Outsiders"', *Journal of Latinos and Education*, 7(1), pp.79-87. doi: 10.1080/15348430701693416.

Martin, P. (2005). ‘Safe language practices in two rural schools in Malaysia: tension between policy and practice’ in Lin, A.M.Y. and Martin, P.W. (eds.) *Decolonisation, globalisation: Language-in-education policy and practice*. Clevedon: Multilingual Matters Ltd, pp. 74-97.

Martin, P. (1999). ‘Bilingual Unpacking of Monolingual Texts in Two Primary Classrooms in Brunei Darussalam’, Language and Education. 13(1) pp.38–58. doi: 10.1080/09500789908666758.

Martiniello, M. (2008). ‘Language and the performance of English language learners in mathematics word problems’, *Harvard Educational Review*, 78(2), pp. 333-368. doi: 10.17763/haer.78.2.70783570r1111t32.

Marx, R.W., Blumenfeld, P.C., Krajcik, J.S., Fishman, B., Soloway, E., Geier, R. and Tal, R.T. (2004). ‘Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform’, *Journal of Research in Science Teaching*, 41(10), pp.1063-1080. doi: 10.1002/tea.20039.

Matriculation and Secondary Education Certificate Examination Board. (2012). Physics Examiners’ Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0004/340690/SECPHYS.pdf (Accessed: 12 November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2013). Physics Examiners’ Report. Available at: https://www.um.edu.mt/matsec/reportscommunication/sec2013 (Accessed: 12 November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2014). Physics Examiners’ Report. Available at: https://www.um.edu.mt/matsec/reportscommunication/sec2014 (Accessed: 12 November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2015). Physics Examiners’ Report. Available at: https://www.um.edu.mt/matsec/reportscommunication/er_sec_2015 (Accessed: 12 November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2016). Physics Examiners' Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0008/340775/SECPHYS.pdf (Accessed: 12 November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2017). Physics Examiners' Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0009/340776/SECPHYS.pdf (Accessed: 12th November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2018). Physics Examiners' Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0009/375840/SECPHYS.pdf (Accessed: 12 November, 2019).

Matriculation and Secondary Education Certificate Examination Board. (2019). Physics Examiners' Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0020/415172/SECPHYS.pdf (Accessed: 8 November, 2020).

Matriculation and Secondary Education Certificate Examination Board. (2020). Physics Examiners' Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0004/457690/SECPhysics2020Examinersreport.pdf (Accessed: 9 November, 2021).

Matriculation and Secondary Education Certificate Examination Board. (2021). Physics Examiners' Report. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0004/479650/ER.SEC24Physics2021.pdf (Accessed: 9 November, 2021).

Matriculation and Secondary Education Certificate Examination Board. (2022). Physics Syllabus. Available at: https://www.um.edu.mt/__data/assets/pdf_file/0013/502141/SEC24PhysicsER.pdf (Accessed: 5 October, 2022).

Mercer, J. (2007). 'The challenges of insider research in educational institutions: wielding a double-edged sword and resolving delicate dilemmas', Oxford Review of Education, 33(1), pp.1-17. doi: 10.1080/03054980601094651.

Mercer, N. (1995). *The Guided Construction of Knowledge: Talk amongst Teachers and Learners*. Clevedon: Multilingual Matters.

Mercer, N. (2000). *Words and minds: how we use language to think together*. London: Routledge.

Mercer, N. (2008). 'The seeds of time: Why classroom dialogue needs a temporal analysis', *The Journal of the Learning Sciences*, 17(1), pp.33-59. doi: 10.1007/s10972-012-9297-9.

Mercer, N. and Dawes, L. (2014). 'The study of talk between teachers and students, from the 1970s until the 2010s', *Oxford Review of Education*, 40(4), pp.430-445. doi: 10.1080/03054985.2014.934087.

Mercer, N. and Dawes, L. (2008). 'The Value of Exploratory Talk', in Mercer, N. and Hodgkinson, S. (eds.) *Exploring talk in school*. California: Sage Publication, Thousand Oaks, pp.37-53.

Mercer, N., Dawes, L., Wegerif, R. and Sams, C. (2004). 'Reasoning as a scientist: ways of helping children to use language to learn science', *British Educational Research Journal*, 30(3), pp.359-378. doi: 10.1080/01411920410001689689.

Mercer, N. and Howe, C. (2012). 'Explaining the Dialogic Processes of Teaching and Learning: The Value and Potential of Sociocultural Theory', *Learning, Culture and Social Interaction*, 1(1), pp.12-21. doi: 10.1016/j.lcsi.2012.03.001.

Michael, J. (2006). 'Where's the evidence that active learning works?', *Advances in Physiology Education*, 30(4), pp.159-167. doi: 10.1152/advan.00053.2006.

Mifsud, J. (2012). *Language practices in science education: problems and possible solutions*. Unpublished B.Ed (Hons.) dissertation. University of Malta.

Miller, J. (2009). 'Teaching refugee learners with interrupted education in science: Vocabulary, literacy and pedagogy', *International Journal of Science Education*, 31(4), pp.571–592. doi:10.1080/ 09500690701744611.

Mills, G. E. (2011). *Action research: A guide for the teacher researcher* (4th Edition). Boston: Pearson.

Ministry of Education. (1999). *Creating the Future Together: National Minimum Curriculum* Malta: Ministry of Education.

Ministry of Education, Employment and the Family. (2012). Towards a quality education for all: *The National Curriculum Framework* Malta: Salesian Press.

Ministry for Education and Employment (2014). *Framework for the Education Strategy for Malta 2014-2024.*

Ministry for Education and Employment. (2015a). *PISA 2015 Malta Report*.

Ministry for Education and Employment. (2015b). *TIMSS 2015 National Report.*

Ministry for Education and Employment (2015c). *Language Education Policy Profile*.

Ministry for Education and Employment (2015d). *The English Benchmark study in Maltese Schools: Technical Report.*

Minner, D.D., Jurist Levy, A. and Century, J. (2010). 'Inquiry-Based Science Instruction—What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002', *Journal of Research in Science Teaching*, 47(4), 474-496. doi: 10.1002/tea.20347.

Mintrop, H. and Sunderman, G.L. (2009). 'Predictable Failure of Federal Sanctions-Driven Accountability for School Improvement - And Why We May Retain It Anyway', *Educational Researcher*, 38(5) pp.353-364. doi: 10.3102/0013189X09339055.

Moore, E., Evnitskaya, N. and Ramos de Robles, S. (2018). 'Teaching and learning science in linguistically diverse classrooms', *Cultural Studies of Science Education*, 13(2), pp.341-352. doi: 10.1007/s11422-016-9783-z.

Morge, L. (2005). 'Teacher-pupil interaction: A study of hidden beliefs in conclusion phases. Research report', *International Journal of Science Education*, 27(8), pp.9-35. doi: 10.1080/09500690500068600.

Msimanga, A. (2015). ‘Code-Switching in the Teaching and Learning of Science’ in Gunstone, R. (ed) *Encyclopedia of Science Education*. Dordecht: Springer, Dordrecht, pp. 1-2.

Msimanga, A. and Lelliott, A. (2014). ‘Talking Science in Multilingual Contexts in South Africa: Possibilities and challenges for engagement in learners’ home languages in high school classrooms’, *International Journal of Science Education*, 36(7), pp.1157-1189. doi: 10.1080/09500693.2013.851427.

Muralidhar, S. (1992). ‘Learning Science in a Second Language: Problems and Prospects’, *Directions*, 14(1), pp.14-28.

Mutlu, A. (2020). ‘Evaluation of students’ scientific process skills through reflective worksheets in the inquiry-based learning environments’, *Reflective Practice*, 21(2), pp.271-286. doi: 10.1080/14623943.2020.1736999.

Norris, S.P. & Phillips, L.M. (2003). How literacy in its fundamental sense is central to scientific literacy, *Science Education*, 87(2), pp.224-240. doi: 10.1002/sce.10066.

Nuthall, G. (1999). ‘Discourse: Classroom Discourse’. [Online]. Available at: http://education.stateuniversity.com/pages/1916/Discourse.html (Accessed: 28 August 2016).

Nyika, A. (2015). ‘Mother tongue as the medium of instruction at developing country universities in a global context’, *South African Journal of Science*, 111(1/2), pp.1-5. doi: 10.17159/SAJS.2015/20140005.

OECD. (2009). *Creating effective teaching and learning environments: First results from TALIS*. Paris: OECD, pp. 19-21.

OECD. (2011). *Education at a Glance 2011: OECD Indicators.* OECD Publishing.

Oral, Y. (2013). ‘The Right Things Are What I Expect Them to Do: Negotiation of Power Relations in an English Classroom’, *Journal of Language, Identity and Education*, 12(2), pp.96-115. doi: 10.1080/15348458.2013.775877.

Osborne, J., and Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: King's College.

Oyoo, S.O. (2011). ‘Language in Science Classrooms: An Analysis of Physics Teachers’ Use of and Beliefs About Language’, *Research in Science Education*, 42(5), pp.849-873. doi: 10.1007/s11165-011-9228-3.

Palincsar, A.S. and Herrenkohl, L.R. (2002). ‘Designing collaborative learning contexts’, *Theory Into Practice*, 41(1), pp.26-32. doi: 10.1207/s15430421tip4101_5.

Pace, Y. (2016). ‘Malta’s state schools lagging behind in international ranking on education’, MaltaToday, 16 December. Available at: https://www.maltatoday.com.mt/news/national/72509/maltas_state_schools_lagging_behind_in_international_education_rankings#.XcqT5K2ZP-b (Accessed: 10 December 2018).

Pierce, K.M. and Gilles, C., (2008). ‘From exploratory talk to critical conversations’ in Mercer, N. and Hodgkinson, S. (eds.) *Exploring talk in school*. California: Sage Publication, Thousand Oaks, pp.37-53.

Pines, A.L. and West, L.H.T. (1986). ‘Conceptual understanding and science learning: An interpretation of research within a sources-of-knowledge framework’, *Science Education,* 70(5), pp.583-604. doi: 10.1002/sce.3730700510.

Powers, A. and Stanfield, C. (2009). ‘Developing science literacy for English language learners’, *AccELLerate*, 2(1), pp.11-12.

Poza, L.E. (2019). ‘*Los Dos Son Mi Idioma*”: Translanguaging, Identity, and Social Relationships among Bilingual Youth’, *Journal of Language, Identity and Education*, 18(2), pp.92-109. doi: 10.1080/15348458.2018.1504682.

Poza, L.E. (2018). ‘The language of sciencia: translanguaging and learning in a bilingual science classroom’, *International Journal of Bilingual Education and Bilingualism*, 21(1), pp.1-19. doi: 10.1080/13670050.2015.1125849.

Prasad, D. (2008). ‘Content analysis: A method of Social Science Research’, in Lal Das, D.K. (ed) *Research Methods for Social Work*. New Delhi: Rawat Publications, pp.174-193.

PRIMAS. (2012). *Promoting Inquiry in Mathematics and Science across Europe*. [Online]. Available at: http://www.primas-project.eu (Accessed: 24 June 2015).

Prince, M. (2004). 'Does Active Learning Work? A Review of the Research', *Journal of Engineering Education*, 93(3), pp.223-231. doi: 10.1002/j.2168-9830.2004.tb00809.x.

Putnam, L. L., and Banghart, S. (2017). Interpretive approaches. *The international encyclopedia of organizational communication*, *117*.

Reeve, J. (2009). 'Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive'*. Educational Psychologist*, 44(3), pp.159-175. doi: 10.1002/9781444395341.ch5.

Ricketts, A. (2011). 'Using Inquiry to Break the Language Barrier', *The Science Teacher*, 78(8), pp.56-58. doi: 101016jlearninstruc201208006.

Riel, M. (2016). *Understanding Action Research*. Center For Collaborative Action Research, Pepperdine University.

Roberts, D. (2007). Scientific literacy/science literacy: Threats and opportunities, in Abell, S.K. and Lederman N.G. (eds.) *Handbook of Research on Science education*. Mahwah, New Jersey: Lawrence Erlbaum Associates, pp.729 – 780.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. and Hemmo, V. (2007). *Science education now: A renewed pedagogy for the future of Europe (EU 22845).* Brussels: European Commission, Directorate-General for Research.

Rollnick, M. (2000). 'Current issues on perspectives on second language learning of science', *Studies in Science Education*, 35(1), pp.93-122. doi: 10.1080/03057260008560156.

Rollnick, M. and Rutherford, M. (1996). 'The use of mother tongue and English in the learning and expression of science concepts: a classroom-based study'. *International Journal of Science Education*, 18(1), pp.91-104. doi: 10.1080/0950069960180108.

Rouet, J.F. (2006). *The Skills of Document Use: From Text Comprehension to Web-Based Learning*. Mahwah, NJ: Lawrence Erlbaum.

Rouet, J.F., Ros, C., Goumi, A., Macedo-Rouet, M. and Dinet, J. (2011). 'The Influence of Surface and Deep Cues on Primary and Secondary School Students'

Assessment of Relevance in Web Menus', *Learning and Instruction*, 21(2), pp.205-219. doi: 10.1016/j.learninstruc.2010.02.007.

Ruhl, K.L., Hughes, C.A., and Schloss, P.J. (1987). 'Using the pause procedure to enhance lecture recall', *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, 10(1), pp.14-18. doi: 10.1177/088840648701000103.

Rutter, T., Edwards, R. and Dean, P. (2016). 'Who's that talking in my class?: What does research say about pupil to pupil exploratory talk that leads to learning?', *Teacher Education Advancement Network Journal*, 8(1), pp.22-32.

Sawyer, R.K. (2008). Optimising Learning: Implications of Learning Science Research. [Online]. Available at: https://www.oecd.org/site/educeri21st/40554221.pdf (Accessed: 31 October 2022).

Scerri, K. (2009). *Speaking the second language in a bilingual society: Form 5 students' attitudes towards speaking English in Malta*. Unpublished M.Ed. dissertation. University of Malta.

Schiefele, U. and Csikszentmihalyi, M. (1995). 'Motivation and Ability as Factors in Mathematics Experience and Achievement', *Journal for Research in Mathematics Education*, 26(2), pp.163-181. doi: 10.2307/749208.

Schmid, S. and Bogner, F. (2015). 'Does Inquiry Learning Support Long-Term Retention of Knowledge?', *International Journal of Learning, Teaching and Educational Research*, 10(4), pp.51-70.

Schmitz, M.J. and Winskel, H. (2008). 'Towards effective partnerships in a collaborative problem-solving task', *British Journal of Educational Psychology*, 78(4), pp.581-596. doi: 10.1348/000709908X281619.

Schoenfeld, A.H. (2013). 'Classroom observations in theory and practice', *ZDM: The international Journal on Mathematics Education,* 45(4), pp.607-621. doi: 10.1007/s11858-012-0483-1.

Schriha, L. and Vassallo M. (2001). *Malta - a linguistic landscape*. Malta: Caxton Printshop.

Schroeder, C.M., Scott, T.P., Tolson, H., Huang, T.-Y., and Lee, Y.-H. (2007). 'A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States', *Journal of Research in Science Teaching*, 44(10), pp.1436-1460. doi: 10.1002/tea.20212.

Schunk, D.H. and Zimmerman, B.J. (2006). 'Competence and control beliefs: Distinguishing the means and the ends', in Alexander, P. and Winne, P. (eds.) *Handbook of educational psychology* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum, pp. 349-367.

Schwartz, M.S., Sadler, P.M., Sonnert, G. and Tai, R.H. (2009). 'Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework', *Science Education*, 93(5), pp.798-826. doi: 10.1002/sce.20328.

Scott, P. (2008). 'Talking a way to understanding in science classrooms', in Mercer, N. and Hodgkinson, S. (eds.) *Exploring talk in schools*. California: Sage Publications, pp.17-36.

Scott, P. (1998). 'Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review', Studies in Science Education, 32(1), pp.45-80. doi: 10.1080/09500690500336957.

Scott Grabinger, R. and Dunlap, J.C. (1995). 'Rich environments for active learning: a definition', *The Journal of the Association for Learning Technology*, 3(2), pp.5-34. doi: 10.1080/0968776950030202.

Scruggs, T.E., Mastropieri, M.A., Bakken, J.P. and Brigham, F.J. (1993). 'Reading versus doing: The relative effects of textbook based and inquiry-oriented approaches to science learning in special education classrooms', *Journal of Special Education*, 27(1), pp.1-15. doi: 10.1177/002246699302700101.

Seinuk Cicek, J., Ingram, S., Friesen, M. and Ruth, D. (2019). 'Action Research: A Methodology for Transformative Learning for a Professor and His Students in an Engineering Classroom', *European Journal of Engineering Education*, 44(1-2), pp. 49-70.

Shwartz, Y., Weizman, A., Fortus, D., Sutherland, L., Merrit, J. and Krajcik, J. (2009). ‘Talking science’, *The Science Teacher*, 7(5), pp.44-47.

Simon, S., Erduran, S. and Osborne, J. (2006). ‘Learning to Teach Argumentation: Research and Development in the Science Classroom’, Internation Journal of Science Education, 28(2), pp.235-260. doi: 10.1080/03057269808560127.

Slevitch, L. (2011). ‘Qualitative and Quantitative Methodologies Compared: Ontological and Epistemological Perspectives’, *Journal of Quality Assurance in Hospitality and Tourism*, 12(1), pp.73-81, doi: 10.1080/1528008X.2011.541810.

Skidmore, D. (2006). ‘Pedagogy and dialogue’, *Cambridge Journal of Education*, 36(4), pp.503-514. doi: 10.21832/9781783096220-007.

Smart, J.B. and Marshall, J.C. (2013). ‘Interactions between Classroom Discourse, Teacher questioning, and Student Cognitive Engagement in Middle School Science’, *Journal of Science Teacher Education*, 24(2), pp.249-267. doi: 10.1007/s10972-012-9297-9.

Smith, J. A. (2004). ‘Reflecting on the development of interpretative phenomenological analysis and its contribution to qualitative research in psychology’. *Qualitative research in psychology*, 1(1), pp.39-54.

Smith, J. and Firth, J. (2011). ‘Qualitative data analysis: application of the framework approach’, *Nurse Researcher,* 18(2), pp.52-62. doi: 10.7748/nr2011.01.18.2.52.c8284.

Solomon, Y. and Black, L., (2008). ‘Talking to Learn and Learning to Talk in the Mathematics Classroom’, in Mercer, N. and Hodgkinson, S. (eds.) *Exploring talk in schools*. California: Sage Publications, pp.73-90

Stake, R.E. (2005). ‘Qualitative Case Studies’ in Denzin, N.K. and Lincoln Y. S. (eds.) *The Sage Handbook of Qualitative Research*. London: Thousand Oaks, New Delhi: Sage Publications, pp.443-466.

Stamovlasis, D., Dimos, A., and Tsaparlis, G. (2006). ‘A study of group interaction processes in learning lower secondary physics’. *Journal of Research in Science*

Teaching: The Official Journal of the National Association for Research in Science Teaching, *43*(6), pp.556-576.

Staver, J.R. and Bay, M. (1987). ‘Analysis of the project synthesis goal cluster orientation and inquiry emphasis of elementary science textbooks’, *Journal of Research in Science Teaching,* 24(7), pp.629-643. doi: 10.1002/tea.3660240704.

Sultana, R. (1992). *Education and national development. Historical and critical perspectives on vocational schooling in Malta*. Malta: Mireva Publications.

Sutherland, J. (2010). *Developing exploratory talk and thinking in secondary English lessons: theoretical and pedagogical implications*. Ph. D. Thesis. University of Sussex. Available at: https://srodev.sussex.ac.uk/id/eprint/6288/ (Accessed: 18 July 2019).

Sutton, C. (1993). ‘Figuring out a scientific understanding’, *Journal of Research in Science Teaching*, 30(10), pp.1215-1227. doi: 10.1002/tea.3660301005.

Swan, M. (2006). *Collaborative Learning in Mathematics: A Challenge to our beliefs and practices*, London. England: National Institute for Advanced and Continuing Education (NIACE) National Research and Development Centre for Adult Literacy and Numeracy (NRDC).

Swan, M. (2005). *Improving Learning in Mathematics: Challenges and strategies*, Sheffield, England: Department for Education and Skills: Standards Unit Publication.

Swain, M. (2006). ‘Languaging, agency and collaboration in advanced second language learning’, in Byrnes, H. (ed.) *Advanced Language Learning: The Contributions of Halliday and Vygotsky*. Continuum, pp. 95–108.

Tafoya, E., Sunal, D. and Knecht, P. (1980). ‘Assessing inquiry potential: A tool for curriculum decision makers’, *School Science and Mathematics,* 80(1), pp.43-48. doi: 10.1111/j.1949-8594.1980.tb09559.x.

Tan, M. (2011). Mathematics and science teachers’ beliefs and practices regarding the teaching of language in content learning. *Language Teaching Research*, 15(3), pp.325-342. doi: 10.1177/1362168811401153.

Taylor, S.J., Bogdan, R. and DeVault, M.L. (2016). *Introduction to Qualitative Research Methods - a guidebook and resource*. New Jersey: John Wiley and Sons, Inc.

Thompson, P. and Gunter, H. (2011). 'Inside, outside, upside down: The fluidity of academic researcher "identity" in working with/in school', *International Journal of Research and Method in Education*, 34(1), pp.17–30. Doi: 10.1080/1743727X.2011.552309.

Tillotson, J.W. (2000). 'Studying the Game: Action Research in Science Education', *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 74 (1), pp.31-34. doi: 10.2307/30189629.

Tobin, K. and McRobbie, C.J. (1996). 'Significance of limited English proficiency and cultural capital to the performance in science of Chinese-Australians', *Journal of Research in Science Teaching*, 33(3), pp.265-282. doi: 10.10 02/(SICI)1098-2736(199603)33:3<265::AID-TEA2>3.0.CO;2-R.

Towers, J. (2010). 'Learning to teach mathematics through inquiry: A focus on the relationship between describing and enacting inquiry-oriented teaching', *Journal of Mathematics Teacher Education,* 13(3), pp.243-263. doi: 10.1007/510857-009-9137.

Ts, S.K., Shum, M., Ki, W.W. and Chan, Y.H. (2007). 'The Medium Dilemma for Hong Kong Secondary Schools', *Language Policy*, 6(1), pp.135-162. doi: 10.1007/s10993-006-9039-y.

Tuan, H.L., Chin, C.C., Tsai, C.C. and Cheng, S.F. (2005). 'Investigating the Effectiveness of Inquiry Instruction on the Motivation of Different Learning Styles Students', *International Journal of Science and Mathematics Education*, 3(4), pp.541-566. doi: 10.1007/s10763-004-6827-8.

Ünsal, Z., Jakobson, B., Molander, B.O. and Wickman, P.O. (2018). 'Science education in a bilingual class: problematising a translational practice', *Cultural Studies of Science Education,* 13(2), pp.317–340. doi: 10.1007/s11422-016-9747-3.

Vella, A. (2013). 'Languages and language varieties in Malta', *International*

Journal of Bilingual Education and Bilingualism, 16(5), pp.532-552. doi: 10.1080/13670050.2012.716812.

Vella, L.A. (2019). ‘Learners’ Attitudes and Ideologies towards English: Implications for the teaching and learning of English in Malta’, Malta Review of Educational Research, 13(2), pp.172-192.

Ventura, F. (2016). ‘Language and Achievement in Science in a Bilingual Context: A Maltese Perspective’, *Malta Review of Educational Research*, 10(2), pp.241-252).

Verawati, N., Hikmawati, H. and Prayogi, S. (2020). ‘The Effectiveness of Inquiry Learning Models Intervened by Reflective Processes to Promote Critical Thinking Ability in Terms of Cognitive Style’, *International Journal of Emerging Technologies in Learning (iJET)*, 15(16), pp.212-220.

Vincini, P. (2003). ‘The nature of situated learning’, *Innovations in learning*, 15, pp. 1-4.

Vygotsky, L.S. (1934). *Thought and language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1978). ‘Mind in Society: The Development of Higher Pedagogical Processes’, in Cole, M. John-Steiner, V. Scribner, S. and Souberman, E. (eds.) *Mind in Society*. Cambridge, MA: Harvard University Press, pp.36-112.

Vygotsky, L. S. (1987). *The collected works of LS Vygotsky: Problems of the theory and history of psychology* (Vol. 3). Springer Science and Business Media LLC.

Walker, L. (2015). *Enabling students to become independent learners*. *Transitions in Undergraduate Mathematics Education.* Birmingham: University of Birmingham.

Walker, M. (2007). *Teaching Inquiry-based Science: A guide for middle and high school teachers*. LaVergne, TN: Lightning Source.

Webb, M. (2009). ‘The teacher's role in promoting collaborative dialogue in the classroom’, *British Journal of Educational Psychology*, 79(1), pp.1–28. doi: 10.1348/000709908X380772.

Wei, L. (2018). ‘Translanguaging as a Practical Theory of Language’, *Applied*

Linguistics, 39(1), pp.9–30. doi: 10.1093/applin/amx039.

Wellington, J. and Osborne, J. (2001). *Language and Literacy in Science Education*. Buckingham: Open University Press.

Wessels, S. (2013). ‘Science as a Second Language: Integrating science and vocabulary instruction for English language learners’, *Science and Children*, 51(1), pp.50-53.

West, C. (2011). ‘Action Research as a Professional Development Activity’, *Arts Education Policy Review*, 112(1), pp. 89-94. Doi: 10.1080/10632913.2011.546697.

Wickman, P.O. and Östman, L. O. (2001). “University Students during Practical Work : Can We Make the Learning Process Intelligible?” in *Research in science Education – Past, Present and Future*, pp.319-324, Springer Publications .

Wilcox, B.R. and Lewandowski, H.J. (2016). ‘Open-ended versus guided laboratory activities: Impact on students’ beliefs about experimental work’, *Physical Review Physics Education Research*, 12(2), pp.1-8. doi: 10.1103/PhysRevPhysEducRes.12.020132.

Willis, J. (2010). *Learning to Love Math: Teaching strategies that change student attitudes and get results*. Alexandria, Virginia: ASCD.

Wilson, J.M. (1999). ‘Using words about thinking: Content analyses of chemistry teachers’ classroom talk’, *International Journal of Science Education,* 21(10), pp.1067-1084. doi: 10.1080/095006999290192.

Windale, M. (2001). *Active teaching and learning approaches in science*. London: Collin Educational.

Wood, D.J., Bruner, J.S. and Ross, G. (1976). ‘The role of tutoring in problem solving’, *Journal of Child Psychiatry and Psychology,* 17(2), pp.89-100. doi: 10.1111/j.1469-7610.1976.tb00381.x.

Yılmaz, S. (2019). ‘Indicators of productive classroom talk and supporting discourse moves: A systematic review for effective science teaching’, *Academy Journal of Educational Sciences*, 3(2), pp.114-137. doi: 10.31805/acjes.642246.

Zammit Mangion, J. (2000). *L-Istorja tal-Edukazzjoni f'Malta*. Malta: PIN.

Appendix 1

Institute of Education

Ethics Application Form: Student Research

All research activity conducted under the auspices of the Institute by staff, students or visitors, where the research involves human participants or the use of data collected from human participants are required to gain ethical approval before starting. *This includes preliminary and pilot studies.* Please answer all relevant questions responses in terms that can be understood by a lay person and note your form may be returned if incomplete.

For further support and guidance please see accompanying guidelines and the Ethics Review Procedures for Student Research http://www.ioe.ac.uk/studentethics/ or contact your supervisor or researchethics@ioe.ac.uk.

Before completing this form you will need to discuss your proposal fully with your supervisor(s).

Please attach all supporting documents and letters.

For all Psychology students, this form should be completed with reference to the British Psychological Society (BPS) Code of Human Research Ethics and Code of Ethics and Conduct.

Section 1 Project details		
a.	Project title	
b.	Student name and ID number (e.g. ABC12345678)	
c.	Supervisor/Personal Tutor	
d.	Department	Academic Department: Curriculum, Pedagogy and

			Assessment .
e.	Course category (Tick one)	PhD/MPhil ☒	EdD ☐
		MRes ☐	DEdPsy ☐
		MTeach ☐	MA/MSc ☐
		ITE ☐	
		Diploma (state which) ☐	
		Other (state which) ☐	

f.	Course/module title	Online MPhil/PhD
g.	**If applicable,** state who the funder is and if funding has been confirmed.	MGSS and confirmed
h.	Intended research start date	May 2017
i.	Intended research end date	June 2018
j.	Country fieldwork will be conducted in Malta *If research to be conducted abroad please check www.fco.gov.uk and submit a completed travel insurance form to Serena Ezra (s.ezra@ucl.ac.uk) in UCL Finance (see guidelines). This form can be found here (you will need your UCL login details available): https://www.ucl.ac.uk/finance/secure/fin_acc/insurance.htm*	Non applicable
k.	Has this project been considered by another (external) Research Ethics Committee?	

	Yes ☐	External Committee Name:
	No ☒ go to Section 2	Date of Approval:

If yes:

- Submit a copy of the approval letter with this application.
- Proceed to Section 10 Attachments**.**

Note: Ensure that you check the guidelines carefully as research with some participants will require ethical approval from a different ethics committee such as the National Research Ethics Service (NRES) or Social Care Research Ethics Committee (SCREC). In addition, if your research is based in another institution then you may be required to apply to their research ethics committee.

Section 2 Project summary

Research methods (tick all that apply)

Please attach questionnaires, visual methods and schedules for interviews (even in draft form).

☒ Interviews	☐ Controlled trial/other intervention study
☐ Focus groups	☐ Use of personal records
☐ Questionnaires	☐ Systematic review ***if only method used go to Section 5.***
☐ Action research	☐ Secondary data analysis ***if secondary analysis used go to Section 6.***
☒ Observation	☐ Advisory/consultation/collaborative groups
☐ Literature review	☐ Other, give details:

Please provide an overview of your research. This should include some or all of the following: purpose of the research, aims, main research questions, research design, participants, sampling, your method of data collection (e.g., observations, interviews, questionnaires, etc.) and kind of questions that will be asked, reporting and dissemination (typically 300-500 words).

Purpose and aims of the research

My research seeks to discover whether there is a relation between the use of inquiry-based learning activities in the Physics' classroom and the students' ability to express themselves in language.

Research Design and Main Research Question

Activities based on inquiry-based learning will be carried out to obtain an insight of whether such activities have an impact on the students' ability to discuss effectively their conclusions in their home language and in an acquired language, i.e. English.

The first part of my research will focus only on my classes. The focus of the IBL activities will be on the level of support the students need, i.e. the nature of scaffolding needed that will enable students to describe a phenomenon and explain it. In other words, the students' ability to express themselves, see patterns and link variables during the inquiry activity using scientific terminology will be delved into.

Probably, since the solution to an IBL activity is generally an open one and students have to articulate and distinguish different solutions, i.e. the nature of inquiry exposes students to language, this might raise the following hypothesis: There is a relationship between the use of IBL tasks and students' ability to express themselves more clearly in language. The use of audio-recording the lesson will also serve to ensure accurate self-assessment of the nature of scaffolding provided to the students, as 'scaffolding efforts should be progressively modified so that student decision making is more extensive and conceptually complex (Wilcox et al., 2015, p.63). Carefully listening and noting what is said is indispensable for obtaining a more accurate response to the hypotheses above. Following on this, several IBL lessons will be planned and carried out with different classes.

Participants and Sampling

The sample for the pilot study will be one of my classes. The participants for the main research will be the rest of my Form 3 classes.

Data Collection

The lessons with my classes will be audio-recorded.

Semi-structured interviews with students will be carried out to obtain an insight of the students' opinion on the influence of the use of IBL on their ability to express themselves in language (written and oral).

Observing other teachers delivering IBL activities will also be considered. This might enable me to obtain an insight of the proper scaffolding needed for students to promote a deep conceptual understanding of fundamental science ideas (through their ability to express themselves in language)

In-depth interviews with some colleagues will also be considered. This might provide an insight into their views about the necessarily scaffolding needed to ensure successful IBL activities in the Physics classroom.

Reference:

Wilcox, J., Kruse, J.W. and Clough, M.P. (2015). 'Teaching Science through inquiry: Seven common myths about this time-honored approach'. *The Science Teacher*, 82 (6), 62-67.

Section 3 Participants

Please answer the following questions giving full details where necessary. Text boxes will expand for your responses.

a.	Will your research involve human participants?	Yes ☒	No ☐ ⇨ *go to Section 4*

b. Who are the participants (i.e. what sorts of people will be involved)? Tick all that apply.

students

☐ Early years/pre-school	☐ Unknown – specify below
☐ Ages 5-11	☐ Adults *please specify below*
☒ Ages 12-16	☐ Other – specify below
☐ Young people aged 17-18	

NB: Ensure that you check the **guidelines** (Section 1) carefully as research with some participants will require ethical approval from a different ethics committee such as the National Research Ethics Service (NRES).

c. If participants are under the responsibility of others (such as parents, teachers or medical staff) how do you intend to obtain permission to approach the participants to take part in the study?

	(Please attach approach letters or details of permission procedures – see Section 9 Attachments.) consent letter from parents and consent from the Director of the Education Department will be sought (this is a request to carry research in Maltese State Schools)
d.	How will participants be recruited (identified and approached)? students in my classes
e.	Describe the process you will use to inform participants about what you are doing. Participants will be informed both verbally and in writing (see consent form). It will also be made clear to the participants that only I will have access to the raw data and that pseudonym will be used to ensure confidentiality.
f.	How will you obtain the consent of participants? Will this be written? How will it be made clear to participants that they may withdraw consent to participate at any time? *See the guidelines for information on opt-in and opt-out procedures. Please note that the method of consent should be appropriate to the research and fully explained.* I will distribute and collect the consent forms myself. It will be clearly stated that they can withdraw consent to participate at any time during the research.
g.	**Studies involving questionnaires:** Will participants be given the option of omitting questions they do not wish to answer? Yes ☐ No ☒
	If **NO** please explain why below and ensure that you cover any ethical issues arising from this in section 8. Semi-structured interviews will be carried out.
h.	**Studies involving observation:** Confirm whether participants will be asked for their informed consent to be observed. Yes ☐ No ☒
	If **NO** read the guidelines (Ethical Issues section) and explain why below and ensure that you cover any ethical issues arising from this in section 8. During the observations I will carry out, I will only observe and keep record of the teachers' role to scaffold and facilitate the students' learning throughout an IBL activity.
i.	Might participants experience anxiety, discomfort or embarrassment as a result of your study? Yes ☒ No ☐

	If **yes** what steps will you take to explain and minimise this? Since the lessons will be audio recorded, the audio recorder device will be used on a regular basis so that the students will get used to the lessons being recorded. Students will also be reminded that only I will have access to the recordings. If **not**, explain how you can be sure that no discomfort or embarrassment will arise?
j.	Will your project involve deliberately misleading participants (deception) in any way? Yes ☐ No ☒
	If **YES** please provide further details below and ensure that you cover any ethical issues arising from this in section 8.
k.	Will you debrief participants at the end of their participation (i.e. give them a brief explanation of the study)? Yes ☒ No ☐
	If **NO** please explain why below and ensure that you cover any ethical issues arising from this in section 8.
l.	Will participants be given information about the findings of your study? (This could be a brief summary of your findings in general; it is not the same as an individual debriefing.) Yes ☒ No ☐
	If **no**, why not?

Section 4 Security-sensitive material Only complete if applicable			
Security sensitive research includes: commissioned by the military; commissioned under an EU security call; involves the acquisition of security clearances; concerns terrorist or extreme groups.			
a.	Will your project consider or encounter security-sensitive material?	Yes ☐ *	No ☒
b.	Will you be visiting websites associated with extreme or terrorist organisations?	Yes ☐ *	No ☒

c.	Will you be storing or transmitting any materials that could be interpreted as promoting or endorsing terrorist acts?	Yes ☐ *	No ☒
*Give further details in **Section 8 Ethical Issues***			

Section 5 Systematic review of research Only complete if applicable			
	Will you be collecting any new data from participants?	Yes ☒ *	No ☐
	Will you be analysing any secondary data?	Yes ☐ *	No ☐
*Give further details in **Section 8 Ethical Issues*** *If your methods do not involve engagement with participants (e.g. systematic review, literature review) **and** if you have answered **No** to both questions, please go to **Section 10 Attachments.***			

Section 6 Secondary data analysis Complete for all secondary analysis				
a.	Name of dataset/s			
b.	Owner of dataset/s			
c.	Are the data in the public domain?	Yes ☐	No ☐	
			***If no,** do you have the permission/license?* Yes ☐ No* ☐	
d.	Are the data anonymised?	Yes ☐	No ☐	
		Do you plan to anonymise the data? Yes ☐ ☐		
		Do you plan to use individual level data? Yes* ☐		
		Will you be linking data to individuals? Yes* ☐		
e.	Are the data sensitive (DPA 1998 definition)?			Yes* ☐
f.				Yes ☐

	Will you be conducting analysis within the remit it was originally collected for?	
g.	**If no,** was consent gained from participants for subsequent/future analysis?	Yes ☐
h.	**If no,** was data collected prior to ethics approval process?	Yes ☐

** Give further details in **Section 8 Ethical Issues***□

□*If secondary analysis is only method used **and** no answers with asterisks are ticked, go to*
Attachments.

Section 7 Data Storage and Security

Please ensure that you include all hard and electronic data when completing this section.

a.	Confirm that all personal data will be stored and processed in compliance with the Data Protection Act 1998 (DPA 1998). *(See the Guidelines and the Institute's Data Protection & Records Management Policy for more detail.)*	
b.	Will personal data be processed or be sent outside the European Economic Area?	Yes ☐ *

*** If yes,** please confirm that there are adequate levels of protections in compliance with the and state what these arrangements are below.

c.	Who will have access to the data and personal information, including advisory/consulta and during transcription? Only I	

During the research

d.	Where will the data be stored? On my laptop and on a pendrive	
e.	Will mobile devices such as USB storage and laptops be used? ***If yes,** state what mobile devices: On my laptop and pendrive ***If yes,** will they be encrypted?: ☒	Yes

After the research

f.	Where will the data be stored? Data will be deleted	
g.	How long will the data and records by kept for and in what format? Until the VIV forwarded to me and it also depends on the outcome of the VIVA	
h.	Will data be archived for use by other researchers?	Yes ☐ * No

***If yes,** please provide details.

Section 8 Ethical issues

Are there particular features of the proposed work which may raise ethical concerns or add to the complexity of ethical decision making? If so, please outline how you will deal with these.

It is important that you demonstrate your awareness of potential risks or harm that may arise as a result of your research. You should then demonstrate that you have considered ways to minimise the likelihood and impact of each potential harm that you have identified. Please be as specific as possible in describing the ethical issues you will have to address. Please consider / address ALL issues that may apply.

Ethical concerns may include, but not be limited to, the following areas:

- Methods
- Sampling
- Recruitment
- Gatekeepers
- Informed consent
- Potentially vulnerable participants
- Safeguarding/child protection
- Sensitive topics
- International research
- Risks to participants and/or researchers
- Confidentiality/Anonymity
- Disclosures/limits to confidentiality
- Data storage and security both during and after the research (including transfer, sharing, encryption, protection)
- Reporting
- Dissemination and use of findings

To carry out a pilot study in Maltese State Schools, consent from the Head of school and the parents of the participants needed to be sought. This was done for the pilot study. Participants were made aware of the reasons they were asked to participate in this study and what would be done with their responses and were assured that only the researcher would have access to the raw data. They were also told about the guarantees of confidentiality, anonymity and non-traceability in the research. It was also explained that their names would be referred to by pseudonyms in both the pilot study and the main study. This is intended as an addition safeguard in protecting the anonymity of the participants (Smith, 2011, p.11). Furthermore, the participants were informed that they can choose to withdraw from the research any time throughout the study. It was also explained to them since only I will have access to the audio recordings, their contribution during the audio recorded lessons will not be taken into consideration during the analysis.

Students will be asked to volunteer for follow up interviews and consent from parents for the interviews will also be sought.

For the main study, consent to carry out the research in Maltese States Schools will be obtained from the Director of the Education department.

Section 9 Further information

Outline any other information you feel relevant to this submission, using a separate sheet or attachments if necessary.

Section 10 Attachments Please attach the following items to this form, or explain if not attached

	Information sheets and other materials to be used to inform potential participants about the research, including approach letters	Yes ☒	No ☐
	Consent form	Yes ☒	No ☐
	If applicable:		
	The proposal for the project	Yes ☐	No ☒
	Approval letter from external Research Ethics Committee	Yes ☐	No ☒

	Full risk assessment	Yes ☐	No ☒

Section 11 Declaration

Yes **No**

I have read, understood and will abide by the following set of guidelines.
☒ ☐

BPS ☒	BERA ☒	BSA ☒	Other (please state) ☐

I have discussed the ethical issues relating to my research with my supervisor.
☒ ☐

I have attended the appropriate ethics training provided by my course.
☐ ☒

I confirm that to the best of my knowledge:

The above information is correct and that this is a full description of the ethics issues that may arise in the course of this project.

Name	Naomi Attard Borg
Date	17th April 2017

Please submit your completed ethics forms to your supervisor.

Notes and references

The approach letter and consent form will be on the same sheet.

Professional code of ethics

You should read and understand relevant ethics guidelines, for example:

British Psychological Society (2009) *Code of Ethics and Conduct*, and (2014) *Code of Human Research Ethics*

or

British Educational Research Association (2011) *Ethical Guidelines*

or

British Sociological Association (2002) *Statement of Ethical Practice*

Please see the respective websites for these or later versions; direct links to the latest versions are available on the Institute of Education http://www.ioe.ac.uk/ethics/.

Disclosure and Barring Service checks

If you are planning to carry out research in regulated Education environments such as Schools, or if your research will bring you into contact with children and young people (under the age of 18), you will need to have a Disclosure and Barring Service (DBS) CHECK, before you start. The DBS was previously known as the Criminal Records Bureau (CRB)). If you do not already hold a current DBS check, and have not registered with the DBS update service, you will need to obtain one through at IOE. Further information can be found at http://www.ioe.ac.uk/studentInformation/documents/DBS_Guidance_1415.pdf

Ensure that you apply for the DBS check in plenty of time as will take around 4 weeks, though can take longer depending on the circumstances.

Further references

The www.ethicsguidebook.ac.uk website is very useful for assisting you to think through the ethical issues arising from your project.

Robson, Colin (2011). *Real world research: a resource for social scientists and practitioner researchers* (3rd edition). Oxford: Blackwell.

This text has a helpful section on ethical considerations.

Alderson, P. and Morrow, V. (2011) *The Ethics of Research with Children and Young People: A Practical Handbook.* London: Sage.

This text has useful suggestions if you are conducting research with children and young people.

Wiles, R. (2013) What are Qualitative Research Ethics? Bloomsbury.

A useful and short text covering areas including informed consent, approaches to research ethics including examples of ethical dilemmas.

Departmental use	
If a project raises particularly challenging ethics issues, or a more detailed review would be appropriate, you may refer the application to the Research Ethics and Governance Administrator (via researchethics@ioe.ac.uk) so that it can be submitted to the Research Ethics Committee for consideration. A Research Ethics Committee Chair, ethics representatives in your department and the research ethics coordinator can advise you, either to support your review process, or help decide whether an application should be referred to the Research Ethics Committee. *Also see' when to pass a student ethics review up to the Research Ethics Committee':* *http://www.ioe.ac.uk/about/policiesProcedures/42253.html*	
Reviewer 1	
Supervisor name	
Supervisor comments	Naomi has now attended to comments from a member of the advisory committee on the first submission of her ethical review.

Supervisor signature		
Reviewer 2		
Advisory committee/course team member name		
Advisory committee/course team member comments	Approved by me after feedback I provided on an earlier draft has been taken into account.	
Advisory committee/course team member signature		
Decision		
Date decision was made	21 April 2017	
Decision	Approved	☐
	Referred back to applicant and supervisor	☐
	Referred to REC for review	☐
Recording	Recorded in the student information system	☐

Once completed and approved, please send this form and associated documents to the relevant programme administrator to record on the student information system and to securely store.

Further guidance on ethical issues can be found on the IOE website at http://www.ioe.ac.uk/ethics/ and www.ethicsguidebook.ac.uk

Appendix 2

Date: ______________________

Parental Consent for Audio Recording Lessons

Dear Parent/Legal Guardian,

My name is Naomi Attard Borg and I am currently working on a research project to obtain an insight of whether the use of inquiry-based learning approaches to the teaching and learning of physics in secondary schools improves the students' understanding and their proficiency in talking about scientific ideas.

As part of the research, I need to audio record several Physics lessons. The audio recordings will be used to help in my analysis of the lessons. No one, except me, will have access to the audio-recorded lessons. Participants can opt to withdraw from participating in this research project at any time.

I would kindly like to ask you to fill in the parental consent form below and return it by ______________________________.

Yours sincerely,
Naomi Attard Borg
Research Student
Institute of Education, University College London, U.K.
Email:

✂ --

I give/do not give consent for my child to be audio recorded during lessons.

(If you do not provide consent, your child's recorded voice will not be used in the data analysis.)

______________________________	______________________
Name of Parent/Guardian	Signature of Parent/Guardian
______________________________	______________________
Name of Student	Class
______________________________	______________________
I.D. of Parent/Guardian	Date

Appendix 3

Investigating Heat Losses

Time	Temperature in Model House 1	Temperature in Model House 2

What can you say about the temperatures?

____

____

____

____

____

____

____

____

____

Appendix 4

Extract from the discussion during plenary of Investigating Heat Losses Activity

Teacher:	What did you observe?
Robert:	House A got a higher temperature.
Teacher:	Can you explain why the temperature in House A was higher than that of House B?
Noel:	Maybe the bulb was stronger?
Teacher:	What do you mean by stronger?
Noel:	It had more power.
Teacher:	What do you mean by ‘more power’?
Noel:	It got hotter faster.
Teacher:	If I tell you that both bulbs were similar, that is, they gave out the same amount of heat, can you now give another reason why the temperature was different?
Noel:	mmmm *(blank face)*
Teacher:	Can someone else explain this?
Yuri:	Maybe because House B was bigger, it needed more time to get so hot?
Teacher:	Can someone else give a different explanation?

No response.

Appendix 5

Density Sandwich – Investigating floating and sinking

Water, cooking oil, maple syrup, dish soap, alcohol (surgical spirit), food colouring

1. Which of the above liquids do you think will float on water?

   ____

2. Which of the above liquids do you think will sink?

   ____

3. Explain your choice.

   ____

   ____

   ____

   ____

Now pour water in the test tube, and then pour the other liquids in any order you decide. Remember to discuss your choice.

4. Which were the liquids that floated on water?

   ____

5. Which were the liquids that sank?

   ____

6. Are the results from your observations and from your predications the same? Can you explain why certain liquids floated and other sank? Do not forget to use the scientific concepts learned!

   ____

   ____

   ____

   ____

Appendix 6

Transcript: Density Sandwich – Investigating floating and sinking

Yuri:	Which of the above liquids do you think will float on water?
Robert:	Oil.
Yuri:	Do we write both?
Robert:	Yes.
Yuri:	Ok.
Yuri:	Which of the above liquids do you think will sink?
Robert:	The rest.
Matthew:	We write maple syrup and dish soap.
Noel:	We have to explain.
Robert:	I don't know what to write.
Matthew:	Neither I.
Yuri:	Let's leave it out.
Robert:	We pour the liquids?
Yuri:	We have to put water first.
Matthew:	I think we should put the ones that sink first, then the ones that float, so they won't mix.
Robert:	I agree.

Students poured the liquids

Yuri: Which were the liquids that floated? We write oil and alcohol.

Matthew: We write maple syrup and soap for the next questions.

Robert and Yuri nodded.

Yuri:	We now write that our predictions were right.
Noel:	We have to explain why.
Yuri:	Heavier liquids sank, not heavy ones floated.
Noel:	Only that?
Yuri:	I don't know what else we can right. You?
Robert:	We write what you said.

Teacher put different densities on the board and asked students to match the densities written with the liquids used during the activity.

Matthew:	Letter A is the density of water as it is 1.
Robert:	I agree.
Yuri:	Letter C is the largest number. It must be of maple syrup.
Robert:	Why?
Yuri:	Maple syrup was the heavier one, so must have the largest number.
Robert:	So, Letter B is of alcohol as it is the smallest number and alcohol was to the top.
Noel:	Yes, yes.
Matthew:	The other one less than one is of oil, so letter E is of oil and letter D is larger than one, so it has to be of the concentrated soap.
Yuri:	Ok.

Discussion at the plenary stage

Teacher:	We have all observed that maple syrup was at the bottom. Which one of these (**referring to the different density values written on the board**) do you think is its density value?
Robert:	C.
Teacher:	Why did you choose letter C? Can you explain your reasoning?
Noel:	Because it is the largest number.
Teacher:	I can see that as well. We are investigating why certain liquids sink and others float on water, so try to explain it using those terms?
Robert:	Maple liquid went to the bottom. Letter C is the largest number, so we think that maple syrup has the largest density, greater than that of water.
Teacher:	A clear explanation.

Appendix 7

Extract from the discussion during plenary of the follow up activity of Density Sandwich - Investigating floating and sinking

Teacher:	What did you observe?
Robert:	The one containing oil floated.
Teacher:	Can you explain why the bottle containing oil floated on water?
Noel:	Oil always floats.
Teacher:	Oil always floats on water. Can you explain this in terms of density?
Noel:	mmmm the density of oil is less than that of water. Yes?
Yuri:	Aha, yes, the density of oil is less than that of water.
Teacher:	All the bottles contained the same volume. Can someone tell me what other variable affects the density of an object?
Robert:	The weight.
Teacher:	What do you mean by weight?
Robert:	How heavy it is.
Teacher:	Ok. What is the formula to calculate the density?
Robert:	Mass over volume. Ahh so mass not weight uff.
Teacher:	Good. So, can someone tell me what was different between these liquids since some sank and some floated?
Matthew:	Their mass.
Teacher:	If a new student joins our class today and wants to know what density is and why some objects floated, and other sank, how would you explain to him what you mean by ‘mass per unit volume’?
Yuri:	I would tell him to put 1ml of the liquid in a measuring cylinder and to find the mass of it. Then, to do the same with the others. He will see that the masses are different, so mass per 1 volume is different, so density of them is different. Those with a density bigger than water will sink, the others will float.
Teacher:	Great. You would surely be of great help to a new classmate.

Appendix 8

Burning off the calories of a Mars bar!!

Part A

a) You and I run up the same flight of stairs in the same amount of time. Who does more work (uses more fuel)? State your reasoning.

____

____

____

b) You run up the flight of stairs in a given amount of time. You run up the same flight of stairs in half the time. Would you do more work (use more fuel) or not? Explain your reasons.

____

____

____

____

c) You and I run up the same flight of stairs in the same amount of time. Who would generate more power? Explain your reason.

____

____

____

____

Investigation: Burning off the calories of a Mars bar!! Part B

Height of 1 step in metres: ________________

Number of steps: _______________

Height of flight of stairs in metres: _____________

Calculate your work done:

____

____

____

____

____

Calculate your power:

____

____

____

____

____

____

From your group, who used more fuel and who generated more power? Explain. ***(Hint: The distance moved was the same for each member of the group).***

____

____

____

____

____

____

Investigation: Burning off the calories of a Mars bar!! Part C

A Mars bar has 280 calories. Determine how many times you would have to run up the staircase at school to burn off the calories. (4.2j=1.0 calorie). Show all the necessary working.

Would I need to run the flight of stairs the same number of times as you do to burn off those calories? Explain why.

____

____

____

____

____

____

____

____

Appendix 9

Phase 1: Teacher-led discussion after teacher wrote: "*Performing a 10-minute exercise will burn off the same number of calories for each and every one of us. True or False?*" on the board.

KerryAnn: No, definitely no. I go for a walk with my mum everyday as she is on a diet and she sweats a lot. I don't. So, she burns off more calories than me.

Robert: I think it is like a car. A 20 horsepower Land Rover would use more **fuel** than a **20 horsepower** Toyota Yaris for the same distance.

Tch: Can you explain why?

Robert: A Land Rover is much heavier than a Yaris. A Land Rover is considered as a **heavy vehicle** while a Yaris is a **light car**. So, the Land Rover is like her mother and she is like the Yaris.

Tch: I understand your comparison. But can you explain why a Land Rover uses more fuel than a Yaris for the same distance?

Robert: The Land Rover is very heavy, so it needs more **fuel** to move forward as it has to carry a lot of **weight.**

Turn Number	**Utterance**	**Inquiry-based learning in Science Main Code**	**Inquiry-based learning in Science Sub-code**	**Language Use**	**Language Code and Explanations**
1 Yuri	Reads question from worksheet: You and I run up the same flight of stairs in the same amount of time. Who does more work (uses more fuel)? State your reasoning.				
2 Noel	Does more work mean who burns off more calories?	SAsQ	SAsQ-EvdL	English	Q-C Asking peers a question to seek clarification of scientific knowledge
3 Robert	Iva, juża aktar **fuel**, eżempju, bejn żewġ persuni, l – aktar wieħed li jiżen juża aktar **fuel**, bħal karozzi. Yes, uses more **fuel**, for example, between two people, the heavier one uses more **fuel**, like cars.	SRQ	SRQ-EvdL	Code-Switching EvdL	R-SC Demonstrating reasoning about the correlation between weight and use of fuel to answer peer's question
4 Yuri	I think the teacher would do more work than us as she is older.	SRQ	SRQ-EvdL	English	P & R-NoSC Predicting a correlation between age and work done

5 Noel	But there is nothing on the paper referring to her age.	SReb	SReb-PEK	English	Questioning of data source and information given on handout
6 Robert	Jien naħseb li għandna nikkonċentraw fuq il – **body wieght** mhux l – eta. I think we should concentrate on our **body weight** not age.	SLog	-------------------	Code-Switching SL	R-NoSC Encouraging group to stick to data source without providing an explanation
7 Noel	So we should write that the teacher would use more fuel to go up the stairs as she weighs more than us as it would take her more time to run the flight of stairs.	SElb	SElb-EvdL	English	R-SC Demonstrating his reasoning of the correlation beween weight and fuel (reason is underpinned by scientific knowledge that our energy is our fuel)
8 Robert	Reads question from worksheet: You run up the flight of stairs in a given amount of time. You run the same flight of stairs in half the time. Would you do more work (use more fuel) or no? Explain your reasons.				
9 Yuri	I think the energy used would be the same.	SReb	SReb-PEK	English	Msc Sharing a misconception as he was unable to correlate that the energy used (work done) depends on the force (weight)
10 Matthew	Għala? Why?	SAsQ	SAsQ-Clr	Maltese	Q-C Asking a question seeking clarification about shared idea
11 Noel	No. It would be more.	SReb	SReb-PSK	English	R-SC Demonstrating his reasoning about the correlation of the two variables (weight and fuel)
12 Robert	Ikun anqas. Jekk tagħmel **exercise** għal **10 minutes**, ha taħraq aktar **calories** milli taħraq f' **5 minutes**. It would be less. If you **exercise** for **10 minutes** you will burn off more **calories** than you would in **5 minutes.**	SReb SUKE	SReb-PSK SUKE-EvdL	Code-Switching EvdL	Msc Comparing when more calories would be burnt off with regards to time of activity when the investigation focused on weight and not time taken to perform the exercise
13 Yuri	But the work done is force times distance, so the person would have still	SReb SUKE	SReb-PEK SUKE-SL	English	R-SC

	used the same amount of energy, but in less time.				Demonstrating his reasoning about the correlation between force and distance and time for the same person
14 Robert	Ahh allura l – **energy used** tkun l – istess, vera, imma f'inqas ħin. Bħallikieku jien niġri **1km in 5 minutes** u nimxi **1km in 20 minutes**. Nuża l – istess **amount of energy** imma f'inqas ħin. Ahh so the **energy used** would be the same true, just in less time. As if I run **1km in 5minutes** and I walk **1km in 20minutes**. I would use the same **amount of energy** but in less time.	SAck-Aff SElb	---------------	Code-Switching SL	R-SC Demonstrating understanding of scientific knowledge (experiential learning)
15 Noel	Mela niktbu dak li qal Robert. So we write what Robert said.	SLog	--------------------	Maltese	Encouraging the group to write down answers on the worksheet
16 Matthew and Yuri	Both nod in agreement.	SAck-Aff	--------------------	-----------------	----------------------
17 Robert	Ok. Xi tfisser **generate more power**? Ok. What does **generate more power** mean?	SAsQ	SAsQ-SL	Code-switching SL	Q-C Asking a question seeking scientific clarification
18 Yuri	I think that since power is the rate of using our fuel, it means who uses the fuel faster.	SRQ	SRQ-EvdL	English	R-SC Demonstrating his reasoning and providing an explanation for it
19 Robert	Qisu min jgħajja l – ewwel. As in who will get tired first.	SElb	SElb-EvdL	Maltese	R-SC Demonstrating his reasoning by comparing two variables (using more energy and getting tired)
20 Yuri	Yes.	SAck-Aff	--------------------	English	Demonstrating his agreement with peer's input

21 Noel	Anki jien hekk naħseb għax xi ħadd kbir ħa jgħajja aktar minn xi ħadd żgħir. Even I think so cause a heavy person would get more tired than a lighter person.	SElb	SElb-EvdL	Maltese	R-NoSC Demonstrating his reasoning about the correlation between weight and use of energy (Possible link with his earlier comment in turn 7)
22 Robert	Imma mhux għal ftit taraġ. But not for just a few stairs.	SReb	SReb-PEK	Maltese	R-NoSC Demonstrating his reasoning that a person who weighs a lot does not get tired for running up a few steps
23 Yuri	But imagine if we had to do it 100 times?	SReb	SReb-PEK	English	R-NoSC Demonstrating his reasoning by correlating time and tiredness
24 Robert	Mhux anki jien ngħajja jekk nitilgħu mitt darba. But even I would get tired by doing it 100 times.	SReb	SReb-PEK	Maltese	R-NoSC Demonstrating his reasoning that a person whose body weight is small also gets tired for running up the stairs 100 times
25 Noel	U huma jgħajjew aktar. And they would get even more tired.	SReb	SReb-PEK	Maltese	R-NoSC Demonstrating his reasoning by correlating body weight and tiredness
26 Robert	Ok.	SAck-Aff	-------------------	Maltese	Agreement with peer's input
27 Noel	So, the teacher would get more tired as she is heavier than us.	SUKE	SUKE-EvdL	English	R-SC Demonstrating his reasoning that a person who weighs more would get more tired when performing the same exercise as a person whose weight is less (correlation between weight, energy and time (power))
28 Matthew	Kif ħa nkejlu – għoli tat – taraġ? How are we going to calculate the height of the staircase?	SAsQ	SAsQ-Log	Maltese	Q-P Asking a procedural question
29 Robert	Inkejlu l – għoli ta **1 step** umbagħad nagħmlu, **times** b'kemm hemm **steps**.	SRQ	SRQ-EvdL	Code-Switching EvdL	R-NoSC Reasoning of how to calculate the height of the staircase in his reply to peer's question

	We measure the height of **1 step** and then **multiply it** by the number of **steps**.				
30 Matthew	U jekk m'humiex kollha l – istess għoli? And if they are not of the same height?	SAsQ	SAsQ-Clr	Maltese	A-MD Asking a question to ensure accuracy when measuring data
31 Noel	Ejja mmorru barra u naraw jekk humiex tal – istess għoli l – ewwel. Let's go outside and see if they are of the same height first.	SLog	--------------------	Maltese	Replying to peer's logistical question.
32 Yuri	Miss, we are going outside. Can I take a measuring tape from the cupboard please?	SLog	--------------------	English	Informing the teacher that they were going out to carry out part of the investigation and to request a measuring tape.
33 Tch	Yes you can.	TchI	TchI-RSQ	English	Replying to student's question.
34 Matthew	Miss, ħabba li l – **height of 1 step** huwa inqas minn **metre** and u aħna ħa nkejluh f' **centimetres**, irridu naqilbuh għal **metres**? Miss, since the **height of 1 step** is less than a **metre** and we are going to measure it in **centimetres**, do we have to convert it in **metres**?	SAsQ	SAsQ-Clr	Code-Switching EvdL	Q-C Informing the teacher about their plan and asking a question seeking clarification about SI units
35 Tch	Why don't you see what your friends suggest?	TchI	--------------------	English	Reminding the students to work as a group by posing a question.
36 Robert	Iva, id - **distance** dejjem inkejluha f' **metres**. Għadni kemm studjajt l - **SI units** u għad – **distance** and **length** nużghu **metres** u allura rridu naqilbuh. Yes, **distance** is always measured in **metres**. Just studied the **SI units** and	SRQ	SRQ-SL	Code-Switching SL	ID Replying to peer's question about the correct unit and suggesting ways to document their measurements

	for **distance** and **length** we use **metres** so we have to convert it.				
37 Yuri	True, True.	SAck-Aff	-------------------	English	Affirming peer's input in turn 36.
38 Robert	**Step** waħda hija **16cm**. 1 **step** is **16cm**.	SLog	-------------------	Code-Switching EvdL	Obs Reporting his observation
39 Noel	In metres?	SAsQ	SAsQ-Log	English	A-RD Asking a logistical question to ensure correct reporting of data.
40 Robert	0.16	SRQ	SRQ-EvdL	English	D-Rep Reporting the data measured in response to peer's questions.
41 Yuri	Yes, 0.16m.	SAck-Aff	-------------------	English	Affirming peer's input in turn 40.
42 Robert	Allura **0.16 x 10steps** huwa **1.6m**. Iktibha ħalli nidħlu lura fil – klassi. So, **0.16 x 10steps** is **1.6m**. Write it down so we go back in class.	SLog	-------------------	Code-Switching EvdL	D-Rep Reporting their calculations and instructing peers to go back in class
43 Noel	Ma naħsibx li l - i**steps** huma kollha tal - istess **height** ta. I don't think that the **steps** are of the same **height** though.	SUnS	-------------------	Code-switching EvdL	A-MD Expressing uncertainty about the data collected
44 Yuri	Let me go up and give you the measuring tape and we measure the height of all the steps together.	SLog	-------------------	English	ID Sharing his idea on how to tackle the uncertainty expressed in turn 43, about the method adopted by the group
45 Robert	Ok. Ħa noqgħod hawn. Ok, I stay here.	SAck-Aff	-------------------	Maltese	Acknowledging peer's input and assisting

46 Noel	X'inhu l – **height**? What is the **height**?	SAsQ	SAsQ-Log	Code-switching EvdL	Q-L Asking a logistical question
47 Robert	1.68m.	SRQ	SRQ-ObS	English	Obs Report his observation
48 Noel	Issa **accurate**. Now we are **accurate**.	SAck-Aff	--------------------	Code-Switching EvdL	
49 Robert	Miss, we need to calculate our work done and power.	No MCode	--------------------	English	Inform the teacher about their next step to follow as written on the handout
50 Tch	OK	No MCode	--------------------	English	Acknowledging students' input
51 Robert	How are we going to calculate our power?	SAsQ	SAsQ-Clr	English	Q-P Asking the teacher a question seeking a procedural assistance
52 Tch	How do we calculate our power?	TchI	TchI-S	English	Replying to the student's question, by posing a question to scaffold their thinking
53 Robert	Work done divided by time taken.	SRQ	SRQ-SL	English	R-SC Replying to teacher's question by demonstrating his reasoning
54 Yuri	Oh, but we don't know how long it takes us to run the flight of stairs.	SLog	--------------------	English	D-RC Point out a difficulty in calculating their power
55 Tch	Can't you find out?	TchI	TchI-S	English	Instructing the students to think about the difficulty pointed out in turn 54
56. Yuri	Yes.	SAck-Aff	--------------------	English	Replying to teacher's question.
57 Noel	Għandna bżonn **stopwatch**. Miss, ħa nerġgħu noħorġu barra. Hemm **stopwatch** fil – **cupboard?** We need a **stopwatch**. Miss, we are going out again. Is there a **stopwatch** in the **cupboard**?	SLog	--------------------	Code-Switching SL	Asking the teacher for the instrument they required and informing her that they needed to go out of the classroom
58 Tch	Iva, hemm wieħed.	TchI	TchI-RSQ	Maltese	Replying to student's question in turn 57.

	Yes, there is one.				
59 Robert	Allura aħna kkalkulajna l – **work done** separati, **using the formula work done is force times distance moved**. So, we calculated our **work done** separately, **using the formula work done is force times distance moved**.	SLog	--------------------	Code-Switching SL	Recapping what they had done to carry out the investigation
60 Noel	Kollha għandna riżultat differenti. We all got different results.	SObS	SObS-EvdL	Maltese	Obs Sharing his observation
61 Yuri	Duhhh. Of course, since our body weight is different.	SUKE	SUKE-EvdL	English	D-Exp Explaining data by explaining peer's observational statement in turn 60
62 Noel	(Giggles) I told you my observation. (Group giggles)	No MCode		English	----------------------
63 Tch	Why did you choose this formula?	TchI	TchI-E	English	Asking a question to invite an explanation
64 Yuri	We chose work done is force times distance moved because since we needed to find out how many times we need to run the flight of steps to burn off the calories of a Mars bar, and calories can be converted into Joules, work done is the energy used and is measured in Joules. We only thought of that.	SRQ SUKE	SRQ-SL SUKE-SL	English	R-SC To reply to teacher's questions and to explain using previously acquired knowledge.
65 Tch	Did you all agree with Yuri?	TchI	--------------------	English	Asking a question to ensure group members were all on track
66 Matthew	Wasalna għaliha flimkien, imma ma nafx eżatt għala. Issa li qed ngħidha, irjalzzajt li aħna nġorru l – **body weight** tagħna u **weight** huwa tip ta **force**. We arrived at it together, but I don't know exactly why. Now that I said that,	SRQ	SRQ-SL	Code-Switching SL	R-SC Demonstrating his understanding that body weight is a type of force (experiential learning)

	I realised that we carry our **body weight** and **weight** is a type of **force**.				
67 Noel	Issa rridu nagħmlu **question 4**. Now we have to do **question 4**.	SLog	--------------------	Code-Switching EvdL	----------------------
68 Tch	Ok	No MCode	--------------------	English	Acknowledging student's statement about what they had still had to do
69 Noel	Reads question from worksheet: From your group, who used more fuel and who generated more power? Explain. ***(Hint: The distance moved was the same for each member of the group).***				
70 Robert	Matthew used more power. Does it mean that the slowest person used more fuel and generated more power Miss?	SObS SAsQ	SObS-SL SAsQ-SL	English	Q-C Asking a question seeking further clarification about the results obtained
71 Tch	How about you see what your friends think about this?	TchI	--------------------	English	Directing students to work as a group
72 Robert	Għala Matthew **generated more power**? Why did Matthew **generate more power**?	SAsQ	SAsQ-SL	Code-Switching SL	Q-C Asking a question seeking scientific clarification
73 Noel	Our fuel is our energy and work done is the energy we used to run up the stairs.	SRQ	SRQ-EvdL SRQ-SL	English	R-SC Demonstrating his reasoning that the work done is the energy used
74 Yuri	Wait, wait. So, since work done is the energy we used, who, who has the largest value used more fuel. I think.	SElb	SElb-EvdL	English	R-SC Demonstrating his reasoning about the correlation between work done and energy used
75 Robert	Oh. Iva. Vera Yuri, naqbel. Allura Matthew uża', **generated more power** għax **his work done was the largest** u mhux għax kien l – i**slowest**. Oh. Yes. True Yuri, I agree. So, Matthew used, **generated more power**	SAck-Aff SElb	-------------------- SElb-SL	Code-Switching SL	R-SC Acknowledging peer's input and demonstrating his reasoning that about the correlation between power generated and the work done

	because **his work done was the largest** and not because he was the **slowest**.				
76 Noel	I don't know whether it is because he was the slowest or not, but definitely because he has the largest work done.	SUnS SElb	-------------------- SElb-SL	English	R-SC Demonstrating his reasoning that about the correlation between power generated and the work done
77 Yuri	So, we have to write that Matthew has the highest power from all of us. Robert used the least fuel because his work done was the least one.	S-Log	--------------------	English	R-SC Demonstrating his reasoning about the correlation between power and work done while suggesting what to write in the worksheet
78 Noel	And the reason why Matthew generated more power was because of his large work done as if he was faster, he would have generated even more power.	SElb SUKE	SElb-SL SUKE-SL	English	R-SC Demonstrating his reasoning while elaborating on peer's input on what to write in the worksheet
79 Yuri	True, cause if we divide his power by a smaller number, we get a larger answer for power.	SAck-Aff SUKE	-------------------- SUKE-SL	English	R-SC Demonstrating his reasoning while agreeing with peer and his earlier input
80 Robert	Allura jfisser li jien naħraq il – **calories** aktar bil – mod għax il – **mass** tiegħi inqas? So, it means that I burn **calories** slower because I have a smaller **mass**?	SAsQ	SAsQ-CL	Code-Switching SL	Q-C Asking a question seeking scientific clarification
81 Yuri	Yes Robert. A person with a small body weight has to run more or exercise more to burn off the calories.	SRQ	SRQ-SL	English	R-SC Demonstrating his reasoning about the correlation of body weight and work done (calories burnt off) in his reply to peer's question
82 Robert	Allura għall – aħħar biċċa rridu niktbu li t – **teacher** trid tiġri t – taraġ inqas drabi minnha kollha għax il – **weight** tagħha huwa aktar minn tagħna, sewwa?	SUKE	SUKE-SL	Code-Switching EvdL & SL	R-SC Demonstrating his reasoning about weight and calories burnt (experiential learning)

	So, for the last part, we have to write that the **teacher** has to run up the stairs fewer times than all of us since she **weighs** more than any of us, right?				
83 Yuri	Yes, and we add that because she weighs more, she generates more power.	SElb	SElb-SL	English	Msc Sharing his misconception that a person who weighs more generates more power
84 Noel	Not necessarily. It depends on how fast or slow she is. So our conclusion should be that since the teacher weighs more than us, she uses more energy to run up the stairs. So, will need to run the stairs less number of times than we do. Burning of calories is the amount of energy used, not power generated.	SReb SUKE	-------------------- SUKE-SL	English	R-SC Demonstrating his reasoning about the rate of doing work (power) and suggesting what to write

Appendix 10

Inquiry Activity Students' sheets

Exploring Light through Prisms

PART A

As a group, describe what you see in the bubbles?

Give a reason why you are seeing what you described in the previous question.

If everything in the classroom was painted white, and you were all wearing white clothes, do you still think we would see colors in the bubbles?

PART B

After looking at the equipment set up on the teacher's desk, discuss the questions below and write down your answers on the same sheet. Remember the ground rules.

What does your group think will happen to the spectrum as you move it away from the prism? Explain why.

What do you think will happen to the spectrum as you move it closer to the prism? Explain why.

What do you think the colour of the beam will be on emerging from the slit? Explain why.

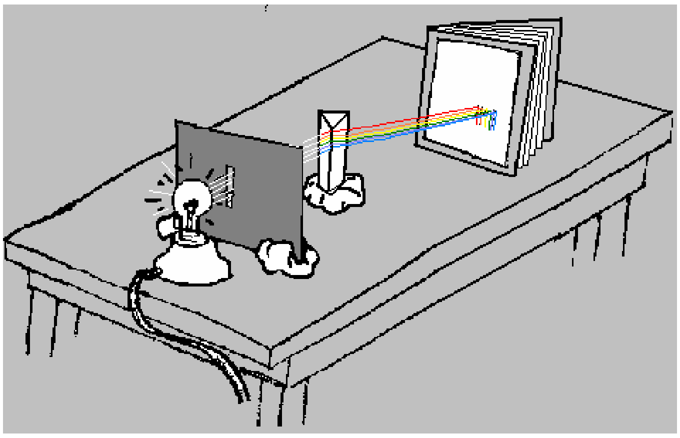
What do you think will happen to the beam after it leaves the prism? Explain your answer.

Inquiry Activity Students' sheets

Exploring Light through Prisms

PART C

1. In groups, make sure that the textbook's position is upright.



2. Switch on the light bulb and answer the following questions in groups.

   Where did the colors come from? Why do you think this happened?

3. Using a pencil, mark the edges of the band of colors on the white viewing paper and label the locations of the different colors, making sure that you don't move the prism or the paper.

4. **What do you think will happen to the different coloured bands of light on the viewing paper if a coloured filter is placed in the path of the light before it enters the prism? Explain your answer.**

5. Place different colored filters in the path of the slit of light, leaving the prism in its place. The filters should be inserted into the path of the light before it enters the prism.

   What do you think will happen? Explain why?
   HINT: Try combining different coloured filters.

6. Record your results and comment on whether the results proved or disproved your previous hypotheses.

Exploring Light through Prisms

CONCLUSION

Based on the results of your investigation, how do you think a filter works? Explain your answer.

What do you think would happen if you placed both a red and a blue filter in the path of the white light?

What can you conclude about white light?

Appendix 11

Turn Number	Utterance	Inquiry-based learning in Science Main Code	Inquiry-based learning in Science Sub-code	Language Use	Notes/ Explanation
1 Tch	Look at the bubble, what can you see?	TchI	TchI-E	English	Asking a question to initiate the discussion
2 Noel	Colours.	SRQ	SRQ-ObS	English	Obs Replying to the teacher's question by reporting his observation
3 Tch	Which colours can you see?	TchI	TchI-E	English	Asking a question to encourage students to report their observation with more detail
4 Robert	Rainbow colours.	SRQ	SRQ-ObS	English	Obs Replying to the teacher's question by reporting his observation
5 Noel	So, we write rainbow colours?	SAsQ	SAsQ-Log	English	Q-L Asking the teacher a logistical question
6 Tch	Remember that you have to discuss, explain and agree first, then you write down the answer.	TchI	--------------------	English	Reminding students about their role in an IBL setting
7 Robert	Naħseb irridu niktbu l – kuluri li rajna. I think that we have to write down the colours we saw.	SLog	--------------------	Maltese	A-RD Ensuring documenting accurate data observed
8 Noel	Eżatt, mhux il – kuluri kollha, dawk li rajna biss. Exactly, not all the colours, just the ones we saw.	SAck-Aff	--------------------	Maltese	A-RD Affirming peer's input to record data accurately
9 Keith	So, we write, Red, Orange, Green, Blue, and pink?	SAsQ	SAsQ-Log	English	Q-L Asking peers which colours should be documented
10 Robert	Jien ma rajntx **pink** u int insejt isemmi li rajna **yellow**.	SRQ	SRQ-ObS	Code-Switching EvdL	A-RD Ensuring documenting accurate data observed

	I didn't see **pink** and you forgot to mention **yellow**.				
11 Noel	U **purple**. And **purple**.	SObS	SObS-EvdL	Code-Switching EvdL	A-RD Ensuring documenting accurate data observed
12 Robert	Kienet qisha **rainbow**, allura rajna aktar **colours**. It looked like a **rainbow**, so we saw more **colours**.	SObS	SObS-EvdL	Code-Switching EvdL	Obs Reporting his observation of seeing 'rainbow colours'
13 Noel	Iva kienet qisha **rainbow**. Yes, it looked like a **rainbow**.	SAck	SAck-Aff	Code-Switching EvdL	Affirming peer's input
14 Keith	Can we do another bubble Miss please?	SAsQ	SAsQ- Log	English	A-RD Asking the teacher to blow another bubble to ensure correct documentation of data observed
15 Tch	Yes sure. The solution is here.	TchI	TchI-R	English	Replying to student's question
16 Robert	Ara, nista nara aħmar, oranġjo, ftit isfar, aħdar, blu u żewġ **shades of purple**. Look, I can see red, orange, a bit of yellow, green, blue and two **shades of purple**.	SObS	SObS-EvdL	Code-Switching EvdL	Obs Reporting his observation about the colours seen on the surface of the bubble
17 Noel	Iktar qisu **violet**. More like **violet**.	SObS	SObS-EvdL	Code-Switching EvdL	Obs Reporting the correct shade of purple
18 Robert	Huma l – istess. They are the same.	SReb	SReb-PEK	Maltese	Rebutting peer's input about the two shades of purple
19 Keith	Le, dawk huma **indigo** u **violet**. No, they are called **indigo** and **violet**.	SReb	SReb-PEK	Code-Switching EvdL	A-RD Ensuring documenting the correct shades of purple

20 Robert	Int għandek **Arts option**, allura int taf aktar fuq il - **colours**. You have **Arts option**, so you must be right about the **colours**.	No Main Code	--------------------	Code-Switching EvdL	Acknowledging the expertise of a peer in relation to the identification or naming of colours.
21 Noel	So, we write red, orange, yellow, green, blue, indigo and violet or violet and indigo?	SAsQ	SAsQ- Log	English	A-RD Ensuring accuracy when reporting observed colours
22 Keith	Indigo and violet.	SRQ	SRQ-ObS	English	A-RD Ensuring documenting the correct order of observed colours
23 Noel	Reads question from worksheet: Give a reason why you are seeing what you described in the previous question.				
24 Keith	Light reflects the colours through the bubble.	SUKE	SUKE-SM	English	Msc Sharing his misconception that the bubble reflected the light instead of refracted
25 Noel	Reads question from worksheet: If everything in the classroom was painted white, and you were all wearing white clothes, do you still think we would see colors in the bubbles?				
26 Robert	Le, la m'hemmx kuluri mhu ħa jirrifletti xejn. No, because it won't reflect anything since there aren't any colours.	SUKE	SUKE-SM	Maltese	Msc Sharing his misconception that the bubble reflected the colours of the surroundings
27 Keith	Dażgur li iva. Il – **beam of light** huwa abjad. Yes, we would. The **beam of light** is white.	SReb SUKE	SReb-PSK SUKE-SL	Code-Switching SL	R-SC Demonstrating his reasoning that the colours of the surrounding do not affect the colours on the bubble because the beam of light is white
28 Robert	Iva il – **beam of light** huwa abjad imma xejn ma jiġri. Yes, the **beam of light** is white but nothing will happen.	SReb	SReb-PSK	Code-Switching SL	Msc Emphasizing his earlier misconception that the bubble reflected the colours of the surroundings

29 Keith	Imma meta l – **white light** daħal ġol – **bubble**, ħareg bħala **colours**, **different colours**. But when **white light** entered the **bubble**, it came out as **colours**, **different colours**.	SReb SObS	SReb-PSK SObS-EvdL	Code-Switching EvdL and SL	Obs Reporting his observation of when white light passed through the bubble and demonstrating his awareness that white light is composed of different colours
30 Robert	Imma taf għala ħareg bħala **different colours**? Għax ġie **reflected**. Kieku kollox ikun abjad, xejn ma jiġi **reflected**. Allura le, l – **answer** huwa le. But do you know why it came out as **different colours**? Because they got **reflected**. If everything is white, nothing will get **reflected**. I think the **answer** is no.	SUKE	SUKE-SM	Code-Switching EvdL and SL	Msc Emphasizing his earlier misconception that the bubble reflected the colours of the surroundings
31 Keith	Id – dawl xorta jigi **reflected**, ghax kieku ma narawx l – **objects**, imma ma jkun hemm **colours**. Light would still be **reflected**, otherwise we won't see the **objects**, but there won't be **colours**.	SReb	SReb-PSK	Code-Switching SL & EvdL	R-SC Reasoning about seeing objects because the objects reflect light
32 Robert	Eżatt. Allura le, ma narawx kuluri. Exactly. So, no we won't see colours.	SAck-Aff	--------------------	Maltese	R-SC & Msc Reasoning that we see objects because objects reflect light and emphasising his earlier misconception that the bubble reflected the colours of the surroundings
33 Noel	Aħna ma rajnix il – **colours** fil – **bubble** għax id – dawl kien **reflected**. Jien naħseb, jien naħseb li kien aktar ħabba li l – **beam of light was passing from one material to another material**. Tagħmel sens għalikom?	SReb SUKE SAsQ	SReb-PSK SUKE-SL SAsQ-Clr	Code-Switching EvdL and SL	R-SC Sharing his reasoning about the context and demonstrating his understanding of the concepts of reflection and refraction (they saw colours on the bubble because the beam of light was passing

	We didn't see the **colours** in the **bubble** because the light was **reflected**. I think, I think that it was more because the **beam of light was passing from one material to another material**. Does it make sense to you?				from one medium to another i.e. refracted)
34 Keith	Eħe, iva, bħal meta l – **beam of light was bent** meta għaddha mill – arja għas – **semi-circular glass block**, fl – **experiment** li għamilna. Ah, yes, like when the **beam of light was bent** on passing from air through **the semi-circular glass block**, in the **experiment** we did.	SAck-Aff SUKE	-------------------- SUKE-SL	Code-Switching EvdL and SL	R-SC Sharing his reasoning to affirm peer's input as well as to elaborate on peer's input (experiential learning)
35 Robert	Allura rridu nirranġaw l – **answer** u niktbu li aħna rajna l – **colours** fil – **bubble** għax il – **bubble bent the beam of light** u tagħtu l – **colours**. So, we have to amend our **answer** and write that we saw the **colours** in the **bubble** because the **bubble bent the beam of light** and it gave it **colours**.	SLog SUKE	-------------------- SUKE-SL	Code-Switching EvdL and SL	R-SC Sharing his reasoning and understanding of his observation
36 Keith	OK. Allura l – **light beam** tgħawweġ ħafna drabi? OK. So, the **light beam** bent several times?	SAck-Aff SAsQ	-------------------- SAsQ-SL	Code-Switching SL	Q-C Asking a question seeking further scientific knowledge on his knowledge that when white light is refracted, different colours are separated as they are refracted to different degrees
37 Robert	Ma nafx. Ma naħsibx. I don't know. I don't think so.	SUnS	--------------------	Maltese	R-NoSc Sharing his reasoning with uncertainty.
38 Noel	Naħseb għandna niktbu dak li qal Robert.	SLog	--------------------	Maltese	----------------------

	I think we should write what Robert said.				
39 Robert	Tgħid nistaqsu lit – **teacher**? Shall we ask the **teacher**?	No MCode	--------------------	Code-Switching EvdL	-----------------------
40 Noel and Keith	Le. No.	No MCode	--------------------	Maltese	-----------------------
41 Noel	Ftakar li aħna rridu niddiskutu u nikkonkludu, mhux niċċekjaw magħha il – ħin kollu. Remember that we have to discuss and conclude, not check with her all the time.	No MCode	--------------------	Maltese	-----------------------
42 Keith	Reads question from worksheet: What does your group think will happen to the spectrum as you move it away from the prism? Explain why.				
43 Noel	**Spectrum** huwa ħafna kuluri. **Spectrum** is a lot of colours.	SUKE	SUKE-SL	Code-Switching SL	R-SC Providing the definition of a scientific term
44 Robert	Kif ħa nispjegawha? How are we going to explain it?	SAsQ	SAsQ-Clr	Maltese	Q-C Asking a question seeking clarification
45 Keith	Naraw ħafna kuluri mma mhux **bright**. We would see a lot of colours, but not **bright**.	SRQ	SRQ-EvdL	Code-Switching EvdL	R-NoSC Sharing his thinking that they would observe a lot of colours.
46 Robert	U jekk tressaqha viċin, il – kuluri ikunu **bright**. And if you move it closer, the colours would be **bright**.	SElb	SElb-EvdL	Code-Switching EvdL	R-NoSC Sharing his thinking on what would happen to the beam of light
47 Noel	U iktar faċli tarafhom.	SElb	SElb-EvdL	Maltese	R-NoSC

	And easier to distinguish.				Sharing his thinking on what would happen to the beam of light
48 Robert	X'jiġifieri? What do you mean?	SAsQ	SAsQ-Clr	Maltese	Q-C Asking a question seeking clarification.
49 Keith	**Perfect red**, **perfect blue** u hekk. Ma nistax nispjegha sewwa. Meta nixgħelu l – **bulb**, nurik x'irrid infisser. **Perfect red**, **perfect blue** and so on. I can't explain it properly. When we switch on the **bulb**, I'll show you what I mean.	SUKE	SUKE-EvdL	Code-Switching EvdL and SL	R-NoSC Sharing his thinking on what they would observe
50 Robert	Allur aktar ma nressquha l – bogħod mill – **light bulb**, aktar ikunu **spead out**, le? Bħal meta tużha **flashlight** u d – **distance** hija kbira. So, the more we move it away from the **light bulb**, the more **spread out** they will be, no? Like when using a **flashlight** and the **distance** is long.	SAsQ SUKE	SAsQ-Clr SUKE-EvdL	Code-Switching EvdL and SL	R-NoSC Demonstrating his understanding using everyday experience to understand context (experiential learning)
51 Keith	Eżatt. Għalhekk ma jkunux **sharp**. Qishom ikunu **blending** ma xulxin. Exactly. That is why they won't be **sharp**. As if they are **blending** with each other.	SAck-Aff SElb	------------------------ SElb-EvdL	Code-Switching EvdL	R-NoSC Explaining his earlier input and elaborating on peer's input
52 Noel	Qishom **smudged** wieħed fuq l – ieħor? Like they are **smudged** onto the next one?	SAsQ	SAsQ-Clr	Code-Switching EvdL	Q-C Asking a question seeking clarification
53 Keith	Il – **beam of light** fit – tarf ma jkunx **strong**, allura naħseb li għandna niktbu li jekk inressqu l – i**spectrum** il –	SUKE SLog	SUKE-SL	Code-Switching EvdL and SL	R-SC

	bogħod, l – i**spectrum** ikun **lighter**. Jekk inressquh viċin, l – i**spectrum** ikun **brighter and sharper**. The **beam of light** at the end of it won't be **strong**, so I think that we have to write that as we move the **spectrum** away, the **spectrum** would be **lighter**. If we move it closer, the **spectrum** would be **brighter and sharper**.				Sharing his reasoning to explain in detail what they have to write to reply to the question in the worksheet
54 Robert	It won't be strong and will be dimmer too.	SElb	SElb-EvdL	English	R-NoSC Sharing his reasoning to elaborate on peer's input
55 Noel	Reads question from worksheet: What do you think the colour of the beam will be on emerging from the slit? Explain why.				
56 Robert	Ikun abjad as l – i**slit** mhux ħa taffettwah. It will be white as the **slit** won't affect it.	SUKE	SUKE-Hyp	Code-switching EvdL	R-NoSC Sharing his reasoning that the slit would not affect the colour of the beam
57 Noel and Keith	Yes.	SAck-Aff	--------------------	English	Affirming peer's input.
58 Robert	Reads question from worksheet: What do you think will happen to the beam after it leaves the prism? Explain your answer.				
59 Robert	Jista jkun li l – **prism** taħdem bħal **bubble**? Could it be that the **prism** acts like the **bubble**?	SAsQ	SAsQ-EvdL	Code-Switching EvdL and SL	R-SC Demonstrating reflecting on understanding by asking a question seeking scientific understanding
60 Keith	X'jiġifieri? What do you mean?	SAsQ	SAsQ-Clr	Maltese	Q-C Asking a question seeking clarification
61 Robert	Ħa naraw **rainbow colours**. We will see the **rainbow colours**.	SUKE	SUKE-EvdL	Code-Switching EvdL	P Predicting what they would possibly observe in his response to peer's question

62 Noel	Għala? Why?	SAsQ	SAsQ-Clr	Maltese	Q-C Asking a question seeking clarification
63 Robert	Għax il – **beam** jgħaddi mill – **air** għal **prism**, u lura għal – **air**, allura **it bends**. Because the **beam** will be passing from **air** to the **prism**, back to **air** again, so **it bends**.	SUKE	SUKE-SL	Code-Switching EvdL and SL	R-SC Demonstrating his reasoning using previously acquired knowledge
64 Keith	And on bending, it refracts different colours.	SElb	SElb-EvdL	English	R-SC Demonstrating understanding of when light is refracted
65 Robert	Eżatt. Exactly.	SAck-Aff	--------------------	Maltese	Affirming peer's input.
66 Noel	Nods in agreement	SAck-Aff	--------------------	-----------------	-----------------------
67 Keith	Reads questions from worksheet: Switch on the light bulb and answer the following questions in groups. Where did the colors come from? Why do you think this happened?				
68 Keith	Prism.	SObS	SObS-EvdL	English	R-NoSC Sharing his reasoning that the prism is producing the colours (spectrum)
69 Robert	Allura l – **prism** qed tipproduċi dawn il – **colours**. So, the **prism** is producing these **colours**.	SObS	SObS-EvdL	Code-Switching EvdL and SL	Obs Reporting their observation that the prism produced the beam of light
70 Tch	What do you think the prism is doing to the white light?	TchI	TchI-S	English	Asking a question to scaffold the students' thinking about refraction
71 Noel	The prism reflected the light.	SRQ	SRQ-SL	English	Msc Sharing incorrect scientific knowledge
72 Tch	What do we see when an object reflects light?	TchI	TchI-E	English	Asking a question to invite an explanation about what happens when an object reflects light
73 Robert	We see that object.	SRQ	SRQ-EvdL	English	R-NoSc Sharing his thinking about reflection

74 Tch	So, if when an object reflects light, we see the object, if a prism reflects light, what are we supposed to see?	TchI	TchI-S	English	Asking a question to scaffold students' thinking about refraction
75 Noel	Refracted not reflected, with the r not i	SRQ	SRQ-SL	English	R-SC Demonstrating his reasoning about reflection and refraction when replying to the teacher's question
76 Robert	Mela rridu nduru l – karta u niċċekjaw xi ktibna. We need to go through the handout and check what we wrote.	SLog	--------------------	Maltese	Encouraging group to amend answers to ensure documenting correct information
77 Keith	Nagħmluha fl – aħħar, ok? We do it after we finish this, ok?	SLog	--------------------	Maltese	---------------------------
78 Tch	If for example I place a red filter here (pointing to the end of the raybox), which colour/colours might I see?	TchI	TchI-S	English	Asking a question to scaffold students' thinking about the use of a coloured filter
79 Robert	The colour of the filter	SRQ	SRQ-EvdL	English	P Predicting what they would observe
80 Tch	Can you explain why?	TchI	TchI-E	English	Asking a question to invite an explanation about why they would observed the colour of the filter
81 Robert	L – **emergent ray** ikun il – kulur tal – **filter** li nużaw. Il – **filter absorbs** il – kuluri l – oħra. The **emergent ray** will be the colour of the **filter** used. The **filter absorbs** the other colours?	SRQ SAsQ	SRQ-SL SAsQ-SL	Code-Switching SL	R-NoSC Sharing his reasoning on the effect on the white beam of light as it leaves the prism when a coloured filter is placed the path of the white beam before the enters the prism.
82 Keith	I think the filter blocks the other colours.	SRQ	SRQ-EvdL	English	R-NoSC Sharing his thinking about the use of the filter
83 Robert	The light was always the colour of the filter.	SObS	SObS-EvdL	English	Obs Reporting directly their observation

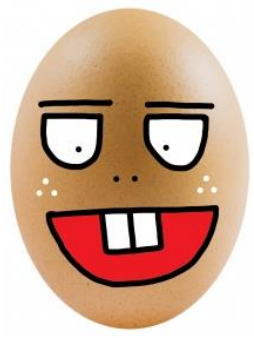
84 Keith	When we used different coloured filters, we only saw the colour of the filter closer to the bulb.	SObS	SObS-EvdL	English	Obs Reporting in detail their observation
85 Robert	So, the filter blocks the other colours.	SUKE	SUKE-EvdL	English	R-NoSC Sharing his reasoning about the effect of filters on the beam of light
86 Noel	Naqbel. I agree.	SAck-Aff	-------------------	Maltese	Affirming peers' inputs.
87 Keith	So the results proved our hypothesis.	SLog	-------------------	English	----------------------
88 Noel	Reads question from handout: Based on the results of your investigation, how do you think a filter works? Explain your answer.				
89 Noel	The filters gave different colours to the light.	SObS	SObS-EvdL	English	Obs Reporting directly their observation about the effect of filters on the beam of light
90 Tch	What else can you say?	TchI	TchI-E	English	Asking a question to scaffold the students' thinking
91 Noel	It changes the colour. No no, it blocks the other colours.	SRQ	SRQ-ObS	English	R-NoSC Sharing his reasoning and demonstrating understanding of how a filter works
92 Keith	The filter allows the colour of it to pass through and it blocks all the other colours.	SElb	SElb-EvdL	English	R-NoSC Sharing his reasoning and demonstrating understanding of how a filter works by elaborating on peer's input
93 Robert	Reads question from handout: What do you think would happen if you placed both a red and a blue filter in the path of the white light?				
94 Robert	Dak l – iktar viċin tal – **light bulb** biss naraw. The one closer to the **light bulb** would be seen.	SUKE	SUKE-Hyp	Code-Switching SL	Obs Reporting directly their observation
95 Noel	Ikun aħmar. It would be red.	SUKE	SUKE-Hyp	Maltese	Obs Reporting directly their observation
96 Tch	What would be red?	TchI	TchI-E	English	Asking a question to invite an explanation

97 Noel	The red filter will be close to the light bulb and we will only see the red colour.	SRQ SUKE	SRQ-EvdL SUKE-Hyp	English	Obs Reporting directly their observation
98 Tch	Can you explain why?	TchI	TchI-E	English	Asking a question to invite an explanation
99 Robert	L – aħmar **will block** il – kuluri l – oħra, imma mhux l – aħmar, allura aħna ma narawx il – kulur blu, għax il – **blue filter** ikun wara ir – **red filter**. The red one **will block** the other colours, but not red, so we will not see the blue colour, as the **blue filter** will be behind the **red filter**.	SRQ SUKE	SRQ-EvdL SUKE-Hyp	Code-Switching EvdL	R-SC Sharing his reasoning and demonstrating his understanding of their observation of how a filter works
100 Tch	Noel and Keith, do you agree?	TchI	-------------------	English	----------------------
101 Noel and Keith	Both nod in agreement	SAck-Aff	-------------------	-----------------	----------------------
102 Keith	Reads question from handout: What can you conclude about white light?				
103 Noel	It can be changed by a prism.	SUKE	SUKE-EvdL	English	R-NoSc Sharing his reasoning and demonstrating understanding of the concept
104 Robert	Iva, bil – **prism**. Yes, by a **prism**.	SAck-Aff	-------------------	Code-switching SL	Affirming peer's input.
105 Keith	F' **colours** differenti. Into different **colours**.	SElb	SElb-EvdL	Code-switching EvdL	Obs Reporting directly their observation
106 Robert	Li huma **red, orange, yellow, green, blue, indigo** u **violet**. Which are **red, orange, yellow, green, blue, indigo** and **violet**.	SElb	SElb-EvdL	Code-switching EvdL	Obs Reporting directly their observation
107 Keith	Dawn il – colours jissejħu l - i**spectrum of white light**.	SElb	SElb-SL	Code-switching	R-SC Providing the definition of a scientific term

	These are called the **spectrum of white light.**			SL	
108 Tch	Can you elaborate a bit more? Remember that you used the word refraction before.	Tchl	Tchl-E	English	Asking a question to to scaffold the students thinking about the concept of refraction
109 Keith	A prism refracts white light into colours (those colours) and produces the spectrum of white light.	SRQ	SRQ-SL	English	R-SC Sharing his reasoning and demonstrating in depth understanding of the concept of refraction by explaining what is happening to white light when it passes through a prism I
110 Keith	Naf li hemm kelma partikolari għaliha, imma ma nistax niftakarha issa. I know that there is a particular word for it, but I can't remember it now.	No MCode	--------------------	Maltese	-----------------------
111 Robert	Forsi nistgħu nżiedu li **when white light enters a prism, the beam of light is refracted, and it produces the colours** u niktbuhom and nispiċċaw b'dak li qal Keith? Maybe we can add that **when white light enters a prism, the beam of light is refracted, and it produces the colours** and we write them and then finish off with what Keith said?	SElb	SElb-SL	Code-Switching EvdL and SL	R-SC Sharing his reasoning and demonstrating his understanding of what was happening and suggesting what the group should add to provide a detailed conclusion
112 Noel	Iva naqbel. Yes, I agree.	SAck-Aff	--------------------	Maltese	-----------------------
113 Keith	Anki jien. Me too	SAck-Aff	--------------------	Maltese-	-----------------------

Appendix 12

WHAT FACTORS INFLUENCE FORCES DURING COLLISIONS?



In our everyday life, safe travel is of high priority. When travelling by various vehicles the most important consideration is the safety of passengers. When developing safety equipment, it is important to understand the forces affecting the body during collisions.

What factors make it possible for the egg to land safely?

1.1 As a team, identify the factors which determine whether an egg breaks when dropped (the factors that affect the egg during collision).

1.2 Design an investigation as a group to study these factors.

1.3 Plan the procedures and record the expected outcomes.

1.4 Carry out your investigation and write down your observations.

1.5 Think of ways of how you could protect the egg from breaking when dropped on a hard surface.

1.6 Carry out your investigation and write down your observations.

1.7 Consult with your group on how the observations correspond to the mechanisms of safety equipment in vehicles.

Appendix 13

Turn Number	Utterance	Inquiry-based learning in Science Main Code	Inquiry-based learning in Science Sub-code	Language Use	Language Codes and Explanations
Phase 1: Class discussion following a video of a car crashing into a wall					
1. Tch	What did you understand?	**TchI**	**TchI-E**	English	---------------------------
2. Yuri	Cars are designed with a crumple zone.	**SRQ**	**SRQ-SL**	English	Obs Reporting his observations from the vidoe
3. Tch	What can you say about the crumple zone?	**TchI**	**TchI-E**	English	---------------------------
4. Yuri	It absorbs the impact energy, so it decreases the force.	**SUKE**	**SUKE-SL**	English	R-SC Sharing his reasoning to explain the use of crumple zone
5. Tch	What about you? (addressing the whole class)	**TchI**	**TchI-E**	English	---------------------------
6. KerryAnn	Is this why old cars don't get so much damaged when they crash?	**SAsQ**	**SAsQ-EvdL**	English	Q-C Asking a question seeking further clarification
7. Robert	Yes, cause the body was not designed with a crumple zone.	**SUKE**	**SUKE-SL**	English	R-SC Sharing his reasoning to explain the correlation between damage caused without a crumple zone
8. KerryAnn	So older cars are better?	**SAsQ**	**SAsQ-EvdL**	English	Q-C Asking a question seeking further clarification
9. Tch	In what ways do you think that they are better?	**TchI**	**TchI-E**	English	---------------------------
10. KerryAnn	They didn't get badly damaged, so they didn't need to pay a lot of money to fix the cars.			English	Obs Reporting what they observed in the video
11. Yuri	They paid a higher price though!			English	R-NoSC
12. Reem	Why?	**SAsQ**	**SAsQ-Clr**	English	Q-C Asking a question seeking further clarification
13. Robert	Ħsara fiżika.	**SUKE**	**SUKE-EvdL**	Maltese	R-NoSC

	Physical damage				
14. Yuri	Cause when a car squashes, there will be less impact energy on the person.	**SUKE**	**SUKE-SL**	English	R-SC Demonstrating his reasoning on the effect on the passengers when crumple zones were not used
15. Reem	Oh, it makes sense.	**SAck-Aff**	**-----------------------**	English	---------------------------
16. Robert	Illum il – ġurnata l – karozzi jispiċċaw diżastru biex jipprotteġu lilek. Huma magħmula b'tali mod li l – karozza ġġarrab ħafna ħsara u int iġġarrab inqas. Nowadays cars end up in a mess for your own safety. They are designed in a way that the car gets a lot of damage and you suffer less.	**SUKE**	**SUKE-EvdL**	Maltese	R-SC Sharing his reasoning of the use of crumple zones
17. Tch	I like the way you described the reason behind the use of crumple zones. So, I am going to give you a handout each. First we are going to concentrate on Part A. We have some instructions written down.	**TchI**	**-----------------------**	English	---------------------------
Utterances 18 – 25: students talking while settling down to work in groups. Utterances were off-task so they were not coded.					
Phase 2: Class discussion and discussion in groups about factors that would affect an egg breaking when dropped					
26 Yuri	The egg will break, depending on the material it lands on.	**SUKE**	**SUKE-Hyp**	English	R-NoSC Sharing his reasoning
27 Robert	U t – **texture**. And the **texture**.	**SUKE**	**SUKE-Hyp**	Code-switching EvdL	R-NoSC Sharing his reasoning
28 Yuri	How it will land as well.	**SUKE**	**SUKE-Hyp**	English	R-NoSC Sharing his reasoning
29 Matthew	X'inridu niktbu allura? What do we have to write though?	**SAsQ**	**SAsQ-Log**	Maltese	Q-L Asking a question seeking logistical information

30 Reem	Jien smajt dak li kontu qed tgħidu u naqbel, ghax int ma tistax tkisser bajda hekk, imma hekk biss. I overheard what you were saying, and I agree, because you cannot break an egg like this, but only like this. (student added gestures: holding something horizontally as well as vertically)	**SElb**	**SElb-EvdL**	Maltese	R-NoSC Sharing her reasoning to elaborate on peer's input in turn 28
31 Tch	So, what do you think are the factors that will affect the egg?	**TchI**	**TchI-S**	English	----------------------------
32 Reem	Speed.	**SRQ**	**SRQ-SL**	English	----------------------------
33 Robert	L – **orientation** ta kif twaddab il – bajda. The **orientation** of how you drop the egg.	**SElb**	**SElb-EvdL**	Code-switching EvdL	R-SC Sharing his reasoning on which factors affect the egg
34 Reem	Yes, cause if it lands horizontally there is a bigger chance for the egg to break.	**SElb**	**SElb-EvdL**	English	P Predicting/hypothesizing, but there is no attempt to present an explanation of why this happens.
35 Yuri	Height and material, it lands on.	**SUKE**	**SUKE-EvdL**	English	R-NoSC Sharing his reasoning on which factors affect the egg
36 Robert	Mela waqt l – **experiment,** l – **orientation** trid tibqa l – istess. So, during the **experiment**, the **orientation** has to be the same.	**SLog**	------------------------	Code-switching EvdL	ID Understanding of fair tests and they are ensuring that they keep the factors they identify constant when testing
37 Yuri	Even the height has to be constant.	**SLog**	------------------------	English	A-RD Understanding of fair tests and they are ensuring that they keep the factors they identify constant when testing

38 Tch	Can you explain to me why you have decided to keep both the height and the orientation constant?	**TchI**	**TchI-E**	English	Asking a question to invite an explanation about their investigative design
39 Yuri	So, so we can focus only on the material. We will be changing the height for every drop for every material, until it breaks when landing on one or not but not on the three of them.	**SRQ**	**SRQ-EvdL**	English	ID Describing correctly how to carry out a fair test
40 Matthew	It also depends on the density of the material. It might not sink in flour because flour is denser than the egg.	**SUKE**	**SUKE-SL**	English	R-SC Sharing his reasoning to identify a possible relevant variable, density and demonstrating that he has an understanding of comparative densities
41 Yuri	But we cannot find the density of flour or sand or the beach. I don't think we should get into that. (referring to density).	**SReb**	**SReb-PSK**	English	Offering a practical explanation which is plausible
42 Matthew	Ok. Ok.	**SAck**	**SAck-Aff**	Maltese	Gave in to Yuri's rebuttal.
43 Tch	Now that you have written some notes, together plan on how you are going to investigate your thoughts/predictions.	**TchI**	**-----------------------**	English	---------------------------
Phase 3: Group discussion while carrying out the investigation to test the factors which affect an egg to break					
44 Yuri	Flour is lighter, softer, so if we drop it from the same height and the same speed, there is a bigger chance that it will not break on flour.	**SUKE**	**SUKE-Hyp**	English	P & R-SC Hypothesizing and sharing his reasoning but no explanation of why this is so in terms of crumple zones is put forward
45 Tch	Have you considered a different surface, maybe a harder one or a softer one?	**TchI**	**TchI-S**	English	Provided guidance to focus on the type of material as the independent variable
46 Robert	Ikun ok jekk inwaddbuha fl – art u fuq il – bank? Is it ok if we drop it on the floor or on the bench?	**SAsQ**	**SAsQ-Log**	Maltese	P and Q-L Asking a question which implies a predication – that the floor and the bench are hard surfaces and will crack the egg

47 Tch	Iva. Yes.	**Tchl**	**Tchl-R**	Maltese	----------------------------
48 Robert	Mela, rridu nżommu l – **height constant** u nwaddbu l – bajda fuq il – bank, id – dqiq u r – ramel u naraw x'jiġri. So, we keep the **height constant** and drop the egg on the bench, flour and sand and we see what happens.	**SLog**	------------------------	Code-switching EvdL	ID Recapping on how they had planned their investigation
49 Matthew	Żgur tinkiser fuq il – bank, iebes ħafna. It will surely break on the bench, too hard.	**SUKE**	**SUKE-EvdL**	Maltese	P Predicting the outcome & explaining why
50 Robert	Irridu nżommu l – **orientation constant** ukoll. We also need to keep the **orientation constant**.	**SLog**	------------------------	Code-switching SL	ID Demonstrating his understanding of controlling variables when carrying out an investigation
51 Noel	Let me hold the ruler. Robert, you drop the egg. Don't throw it, just drop it so speed won't change.	**SLog**	------------------------	English	ID Taking the lead during the investigation & showing awareness that measurements taken must be systematic
52 Yuri	Let's try from the 30cm mark.	**SLog**	------------------------	English	D-RC Suggesting a procedural aspect to record the data
53 Robert	Ok. Taqblu li qeda fuq it – **30cm mark**? Ma nistax nara sew minn hawn fuq. Ok. Do you agree that it is on the **30cm mark**? I can't see properly from up here.	**SAsQ**	**SAsQ-Log**	Code-switching EvdL	A-C Ensuring accuracy which is an important process skill when carrying out an experiment/ investigation
54 Noel	Yes. (Yuri nods)	**SAck-Aff**	------------------------	English	Replying to peer's question
55 Yuri	Remember to always drop it like this.	**SLog**	------------------------	English	A-RD

					Ensuring systematic measurements when carrying out the investigation as he insists the egg is dropped always in the same way
56 Robert	OK (giggles)	**SAck-Aff**	------------------------	-----------------	----------------------------
Egg was dropped on sand and flour.					
57 Yuri	Come on. Try it on the bench now. (giggles)	**SLog**	------------------------	English	ID Suggesting a procedural aspect
The egg broke when dropped on the bench.					
58 Robert	We don't need to try it from a higher height on the bench, as it will surely break.	**SLog**	------------------------	English	ID Since the egg broke, Robert predicted that the egg would surely break if the height increases.
59 Tch	Have you discussed 1.2?	**TchI**	------------------------	English	----------------------------
60 Noel	Yes.	**No Main Code**	------------------------	English	----------------------------
61 Tch	What have you come up with?	**TchI**	**TchI-E**	English	----------------------------
62 Noel	Meta l – bajda waqgħet minn distanza qasira, inkisret biss fuq il – mejda, pero meta żidna d – distanza, inkisret fuq ir – ramel imma ma nkisritx fid – dqiq. When the egg was dropped from a short distance, it only broke on the table, while when we increased the distance, it broke on sand but it didn't break on flour.	**SRQ**	**SRQ-ObS**	Maltese	Obs Reporting directly their observation & demonstrating his understanding to identify a relationship between height and whether the egg breaks
63 Tch	What can you say about this? Can you explain why this happened?	**TchI**	**TchI-E**	English	----------------------------
64 Keith	Ħabba li d – dqiq huwa **soft**, il – bajda baqgħet nieżla, qisu mewwet l – **impact**. Since the flour is **soft**, the egg sank, and so it kind of killed (decreased) the **impact**.	**SRQ**	**SRQ-SL**	Code-switching EvdL and SL	D-Exp Explaining their observation

65 Robert	Id – dqiq qisu kien il – **crumple zone**. The flour acted like the **crumple zone**.	**SElb**	**SElb-SL**	Code-switching SL	D-R Inferring from evidence and/or observation: applying knowledge from cars context to eggs context
66 Tch	Tista' tispjega ftit aktar fid – dettal? Can you explain it a bit more in detail?	**Tchl**	**Tchl-E**	Maltese	----------------------------
67 Robert	Id – dqiq tferrex u l – bajda baqgħet nieżla aktar l – isfel fil – bowl, it **– time of hitting**, jew **contact** bejn il – bajda u d – dqiq żdied, allura l – **energy**, mmm **speed**, naqas bil – mod. The flour spread and so the egg went further down in the bowl, increasing the **time of hitting**, or **contact** of the egg and the flour, so **energy** mmm **speed** decreased slowly.	**SRQ**	**SRQ-SL**	Code-switching	D-Exp Explaining of previous contribution: reflects good understanding of the physics behind crumple zones as well as articulate it well
68 Keith	Jien naħseb li kieku użajna bowl aktar fonda, l – bajda ma kienitx tinkiser fuq ir – ramel. I think that if we had used a deeper bowl, the egg wouldn't have broken on sand.	**SUKE**	**SUKE-Hyp**	Maltese	R-NoSC Sharing his reasoning to speculate based on evidence
69 Robert	Qisu tkun tilfet l – i**speed** u titnaqqas is – saħħa tal – **impact**. Kind of it would have lost the **speed** and decreased the strength of the **impact**.	**SElb**	**SElb-SL**	Code-switching SL	R-SC Sharing his reasoning to demonstrate good physics in terms of the relationship between time of impact and force of impact in his attempt to explain previous contribution
70 Keith	Eżatt. Exactly.	**SAck-Aff**	------------------------	Maltese	----------------------------
71 Tch	Nodded.	**SAck-Aff**	------------------------	-----------------	----------------------------
Phase 4: Group discussion while designing the investigation and testing how to protect an egg when dropped					

72 Noel	X'materjal ħa nużghu għat – tieni parti? What kind of materials are we going to use for part two?	**SAsQ**	**SAsQ-Log**	Maltese	Q-L Asking a question seeking logistical information
73 Robert	Aħna rridu nipproteġu l – bajda meta tinżel fuq **hard surfaces**, le? We need to protect the egg when it lands on **hard surfaces**, no?	**SAsQ**	**SAsQ-Clr**	Code-switching EvdL	Q-C Asking a question seeking clarification
74 Matthew	Yes. Bubble wrap or kite paper.	**SLog**	------------------------	English	ID Suggesting ways how carry out the investigation
75 Robert	Anki jekk ingeżwruha f' **tissues**. Even if we wrap in **tissues**.	**SLog**	------------------------	Code-switching EvdL	ID Suggesting ways how carry out the investigation
76 Matthew	Nistgħu nipproteġuha wkoll billi ndawru l – **cotton** magħha. We can also protect it by wrapping **cotton** around it.	**SLog**	------------------------	Code-switching EvdL	ID Suggesting ways how carry out the investigation
77 Keith	Nistgħu wkoll innaqsu l – **height** u nwaddbuha **horizontally**. We can also decrease the **height** and drop it **horizontally**.	**SLog**	------------------------	Code-switching SL	ID Suggesting ways how carry out the investigation
78 Matthew	Ma nistgħux inwaddbuha fid – dqiq la ma nkisritx? Can't we just drop it in flour since it didn't break?	**SAsQ**	**SAsQ-Log**	Maltese	Q-P Asking a question, seeking procedural information
79 Noel	Le, għax irridu nużgħu **bowl** vojta. Irridu naħsbu f'xi ħaġa biex nipproteġuha meta tillandja fuq **tray** vojt. No, because we need to use an empty **bowl**. We have to think of how we can	**SRQ**	**SRQ-EvdL**	Code-switching EvdL	A-RD Ensuring sticking to accuracy when recording data

	protect it when it lands on an empty **tray**.				
80 Matthew	Mela **cotton** madwarha. Then **cotton** around it!	**SLog**	------------------------	Code-switching EvdL	ID Emphasising his previous input in turn 76
81 Noel	Jien kont qed naħseb forsi nibnu xi struttura u l – bajd jinżel fuqha. I was thinking of maybe building a structure and the eggs will land on it.	**SLog**	------------------------	Maltese	ID Suggesting ways how to carry out the investigation
82 Keith	Nistgħu nwaddbuha minn għoli ta **half a metre**. We can drop it form a height of **half a metre**.	**SLog**	------------------------	Code-switching EvdL	ID Suggesting ways how to carry out the investigation
83 Noel	Xorta tinkiser fuq **tray** vojt. Tiftakar li nkisret fuq il – bank minn għola ta **30cm**? It will still break on an empty **tray**. Do you remember that it broke on the bench from a height of **30cm**?	**SReb**	**SReb-PM**	Code-switching EvdL	P Predicting what might happen based on his earlier observation
84 Robert	Forsi nistgħu nimlew il – **bowl** bl- ilma? Maybe we can fill the **bowl** with water?	**SAsQ**	**SAsQ-Log**	Code-switching EvdL	ID Suggesting ways how to carry out the investigation
85 Noel	Irridu nipproteġu l – bajda. Ġieli raju xi struttura magħmula mill – qasab fuq youtube biex tipproteġi l – bajda? Xi ħaġa hekk. We have to protect the egg. Have you ever seen a structure made out of cane on youtube to protect an egg? Something like that.	**SRQ** **SAsQ**	**SRQ-EvdL** **SAsQ-Log**	Maltese	ID Emphasizing his suggestion in turn 81 on how to carry out the investigation
86 Matthew	Nistgħu nagħmulha fl – islime.	**SRQ**	**SRQ-EvdL**	Maltese	ID

	We can put it in slime.				Suggesting another way to carry out the investigation
87 Keith	Jekk nagħmlu ħafna slime madwar il – bajda, tkun qisha tip ta protezzjoni. If we put a lot of slime around the egg, it will be a sort of protection.	**SElb**	**SElb-EvdL**	Maltese	R-NoSC Sharing his reasoning without a scientific concept on how to protect the egg
88 Noel	Ejja naħsbu f'xi ħaġa oħra, ħalli jekk tinkiser meta tkun fl – islime, xorta nkunu nistgħu nkomplu naħdmu fuq il – proġett. Let's think of something else as well, just in case it breaks when covered in slime, we would still be able to work on the project.	**SLog**	------------------------	Maltese	Suggesting thinking of another way how to protect the egg just in case their other ways fail, in order to be able to carry out the investigation
89 Robert	Għaliex issuġġerejt l – islime? Why did you suggest slime?	**SAsQ**	**SAsQ-Clr**	Maltese	Q-C Asking a question seeking clarification on the use of slime
90 Keith	Għax ħabba li qisu **jelly**, **it will absorb the impact**. Because since it is like **jelly**, **it will absorb the impact**.	**SRQ**	**SRQ-SL**	Code-switching SL	R-SC Sharing his reasoning about the effect of slime on the impact to explain to peer
91 Robert	Imma kif l – islime ħa jibqa mwaħħal mal – bajda? But how will the slime remain stuck to the egg?	**SAsQ**	**SAsQ-Clr**	Maltese	Q-C Asking a question seeking further clarification
92 Noel	Jekk l – islima jitgħaffeġ, il – bajda xorta tibqa fuqu. If the slime gets squashed, the egg would still stay on it.	**SRQ**	**SRQ-EvdL**	Maltese	R-NoSC
93 Matthew	Inġibu bajda mgħollija mid – dar.	**SOff**	------------------------	Maltese	----------------------------

	We bring a boiled egg from home. (giggles)				
94 Keith	Imma aħna li l – qoxra ma tinkisirx irridu, mhux li l – isfar ma joħroġx. But what we need is the shell not cracking, and not that the egg yolk doesn't spill.	**SLog**	------------------------	Maltese	A-RD Ensuring that they carry out the investigation properly
95 Noel	Li ma tinkiser xejn. Il – qoxra. That it doesn't crack at all. The shell.	**SLog**	------------------------	Maltese	A-RD Emphasizing accuracy when carrying out the investigation
96 Reem	Watch this guys. I made a dough with the broken eggs, you see **I** didn't waste, **I** recycled, and the egg didn't break even when dropped from a height of 150cm.	**SObS**	**SObS-EvdL**	English	Sharing her group observations from the investigation they had just carried
97 Maya	We are geniuses. (everybody laughed)	**SOff**	------------------------	English	----------------------------
98 Matthew	Hemm bżonn nippruvaw metodi differenti? Do we need to try different methods?	**SAsQ**	**SAsQ-Log**	Maltese	Q-L Asking a logistical question
99 Tch	Intom tridu tiddeċidqu bħala grupp. You have to decide as a group.	**TchI**	------------------------	Maltese	----------------------------
100 Matthew	Mhux ċert x'irridu nagħmlu? I am a bit lost about what we have to do now.	**SUnS**	------------------------	Maltese	????????????????
101 Tch	Have you asked your group for help? Do you remember what the video was about?	**TchI**	**TchI-S**	English	----------------------------
102 Matthew	Yes and I understood that the flour absorbed the force of the egg.	**SRQ**	**SRQ-SL**	English	D-Exp Explained what he understood from the investigation carried out
103 Tch	Why did the flour absorb the force/ impact caused by the egg?	**TchI**	**TchI-E**	English	----------------------------

104 Matthew	Cause the flour moved, scattered actually, and the egg kept going in the bowl and the time of contact between the egg and flour was long.	**SRQ**	**SRQ-SL**	English	D-Exp Explaining what he understood from the investigation carried out
105 Tch	So, since the flour is soft and it increased the impact time, it also absorbed the impact, the energy. How can we use this knowledge to protect the egg when it hits a hard surface, like the floor or the bench?	**TchI**	**TchI-S**	English	----------------------------
106 Matthew	U l – għaġina kellha l – istess effett tad – dqiq. And the dough has the same effect of flour.	**SRQ**	**SRQ-EvdL**	Maltese	Obs Reporting directly their observation to back his previous explanation
107 Tch	The dough and the flour had the same effect on the egg, right.	**TchI**	------------------------	English	----------------------------
108 Matthew	Ok I get it now. We need to do something so the impact time increases so the egg won't break.	**SUKE**	**SUKE-SL**	English	ID Explaining what he understands they need to do w then carrying out the investigation
109 Noel	Nagħmlu l – għaġina u nippruvawha umbagħad niktbu kif ipproteġejna l – bajda? Shall we make a dough and try it out and then write about how we protected the egg?	**SAsQ**	**SAsQ-Log**	Maltese	ID Suggesting ways how to carry out the investigation based on the observations the other group had shared
110 Keith	Ejja nippruvawha minn għoli ta **150cm**. Let's try it from a height of **150cm**.	**SLog**	------------------------	Code-switching EvdL	D-RC Suggesting a procedural aspect to record the data
111 Yuri	Since the egg didn't break when we covered it in dough, we can write that the dough acted like the crumple zone and absorbed the force of impact. This did not damage the egg like the crumple	**SObS** **SUKE**	**SObS-SL** **SUKE-SL**	English	D-Exp & R-SC Explaining the data from their observations and applied the knowledge gained to explain it

	zone avoids the persons getting hurt in a crash.				
112 Robert	We have to add that because the dough acted like the crumple zone, it also increased the contact time between the egg and the hard surface. Then we write your last sentence. Do you all agree?	**SElb-SL**	**SElb-SL**	English	R-SC Explaining his peer's input in turn 111 in a more sophisticated way
113 Noel	Iva. Yes.	**SAck-Aff**	------------------------	Maltese	-----------------------
114 Matthew	Nodded	**SAck-Aff**	------------------------		-----------------------

Appendix 14

Interview

Preparatory statements

- To explain that the interviews will be tape-recorded to completely eliminate the necessity of note- taking.

- To explain that the purpose of the group discussions is to find out how students view learning science. The more honest and clear their information is, the easier it is for us to know how to improve our teaching.

- To assure all students that no names, or faces, will be used in this project. The identity of all the students will be kept totally confidential.

- To offer to share the results of the interview with the students.

Interview questions

1. How did you feel about learning Physics before you started Year 9? (Students learn science during years 7 and 8, while Physics is compulsory in state schools as from Year 9).
2. Do you prefer expressing yourself in English or Maltese in class?
3. Does it make any difference to you whether discussions are in Maltese or in English? Why?
4. How do you feel about the type of language used in the Physics classroom? (Do you prefer the teacher to talk in Maltese or in English?) Why?
5. How do you feel about talking/discussing in the Physics classroom?
6. How do you feel about the scientific language (words/terms which are scientific?)
7. What can you say about the difference between learning Physics using everyday language and then learning the scientific terms or learning Physics using scientific terms only?
8. How do you feel about the writing used in the Physics classroom (what you write and what the teacher writes)?

9. How do you feel when you are doing Physics?
10. Which type of lessons did you enjoy most? Can you explain why? (To mention the following if students ask for assistance: demonstration traditional, inquiry activities) Can you explain why?
11. How did you feel during your first inquiry activity?
12. How do you feel about inquiry activities in the Physics classroom now that you have experience learning through a number of these activities?
13. Are there ways in which the inquiry activities have helped you to learn Physics?' Are there other ways?
14. If you had to provide feedback about your experience in the Physics classroom, what would you recommend for effective teaching and learning?

Appendix 15

Pilot Interview Responses

1. **How did you feel about learning Physics before you started Year 9?**

Reem: I didn't feel happy when I found out I had to learn Physics because everyone told me it was hard.

Liane: I was very excited about learning a new subject but also scared since students who were older than me complained about it being difficult.

2. **Do you prefer expressing yourself in English or Maltese in class?**

Reem: Mostly in English.

Liane: I prefer in Maltese.

3. **Does it make any difference to you whether discussions are in Maltese or in English? Why?**

Reem: I prefer Maltese as it is my native language, but as I said, if there is a students who only understands English, I think the lesson should be in English for everyone to understand.

Liane: Yes it does, because I understand more in Maltese and I am also more fluent and confident when speaking in Maltese.

4. **How do you feel about the type of language used in the Physics classroom? (Do you prefer the teacher to talk in Maltese or in English? Why?**

Reem: I don't mind as I understand both languages. But I think if there are some students who are English speakers and don't understand Maltese, I think the teacher should speak in English.

Liane: I prefer if both languages are used. Maltese as an explanation and when we discuss things but the technical physics words in English. As an explanation I prefer Maltese.

5. **How do you feel about talking/discussing in the Physics classroom?**

Reem: I feel like discussing and hands on activities are crucial because it is good for both parties, the teacher would know whether the students are understanding or no and good for the students because they would understand more.

Liane: I like to talk. We learn from each other. And the way you used to put the questions for us made us think a lot, not just remember what we had learned before. We had to use our brains and learn more from each other.

6. **How do you feel about the scientific language (words/terms which are scientific?)**

Reem: Once I understand them, they don't bother me.

Liane: Some of them are too complicated. Once I understand them, they don't bother me.

7. **What can you say about the difference between learning Physics using everyday language and then learning the scientific terms or learning Physics using scientific terms only?**

Reem: I would prefer we learn Physics using scientific terms only and then it is up to us to ask if we don't understand the scientific terms. But if it is an inquiry activity I prefer to use the words I know and then the teacher tells me how to say them in scientific terms. This helps me do the activity better.

Liane: Using everyday language is easier for me to remember. I prefer learning using everyday language and then learn the proper Physics terms once I understood the theory.

8. **How do you feel about the writing used in Physics classroom (what you write and what the teacher writes)? For example, when doing experiments and writing the conclusions?**

Reem: When I do the experiments, I don't mind writing the conclusions as I understand better what was done and know what I have to write. If the teacher does a demonstration, I don't find it that easy to write the conclusion. I ask the teacher or my friends to help me.

Liane: When we do the experiment as a group, I understand the experiment and I find writing the lab report and even the conclusion quite easy, with the help of the notes. Also, last year, you used to ask us questions that helped us think, kind of helped us without helping us, and that made me better in knowing how to write and what to write.

9. **How do you feel when you are doing Physics?**

Reem: I used to like it. It was fun and interesting. Now in Year 11, every time I go into the Physics classroom I start falling asleep. I lost interest and I am finding it harder.

Extra question: Why are you finding it harder?

The teacher is nice, but he just talks a lot and we listen. I find it hard to follow what he is saying.

Liane: I loved it last year. This year I find it very boring. The topics are boring and teacher talks a lot and we just copy.

Extra question: Why did you love doing Physics last year?

It was interesting, fun. I enjoyed the discussions and working in groups. We could talk and share ideas and learn from each other. We said something and then you helped us add to it and learn the physics of it.

10. **Which type of lessons did you enjoy most? (Discussing as a class, teacher demonstrates an experiment, carrying out an experiment yourself, teacher explains concepts or inquiry activities (like the one of light and prisms and the one of dropping the egg))? Can you explain why?**

Reem: The lessons I liked most were the ones of the mars bar, the one of the light and prism and when we dropped the egg. They were very hands on, fun and I understood what we were doing and also the physics of them.

Liane: I really like carrying out the experiment or the activity myself. Since I concentrate more during hands on, I understand what I am doing. I concentrate more during hands on work, not only in Physics.

11. **How did you feel during your first inquiry activity?**

Reem: It was fun as I got to do something not just sitting down and listening. That way it also helped me learn as I paid more attention to what I needed to do and to what I was doing.

Liane: It was exciting. It was something we had not done before. We planned together and moved around not just sitting down and listening to the teacher.

12. **How do you feel about inquiry activities in the Physics classroom now that you have experience learning through a number of these activities?**

Reem: I still think they are a crucial part of learning because inquiry activities helped me pay more attention and have fun while learning something important. I still remember what I learnt during those lessons. I miss them.

Liane: They helped me learn Physics more. I enjoy doing things myself, I concentrate more and understand better. Also, when we talk, we learn from each other and you kind of realise where you are wrong and learn the thing properly. This year it is very boring. The teacher just explains and demonstrates things himself and we just copy what he writes on the board.

13. **Are there ways in which inquiry activities (Mars Bar, light and prism, egg drop) have helped you to learn Physics?**

Reem: When it is just the students listening to the teacher I find it very boring and I get sleepy, but when it came to us doing the inquiry activities, I paid more attention and learned the Physics more.

Liane: Yes. This year the teacher gives us an equation and we have to learn what the letters stand for and work out the problems. During the Mars bar inquiry, we had already learned the equation for work done and what the letters stand for, and we could see how it could be used in reality. For the egg drop activity, we had already learnt the topic forces, but we got to test them out ourselves. Both these activities showed us when Physics is used in real life.

14. **If you had to provide feedback about your experience in the Physics classroom, what would you recommend for effective teaching and learning?**

Reem: Last year was a great year for me. I learned a lot because we had a lot of interesting activities and discussions and I understood the Physics well. When this year we work past papers, I get the answers of the questions of what we learned last year all correct. I think there should be more activities and discussions like we used to do last year.

Liane: A lot of hands on activities like we did last year and the discussions to learn the theory together. When we just sit down, write and listen to the teacher it gets boring and you don’t really follow, and we talk in the language we are more fluent in, so we understand better.

Appendix 16

Interview Responses

1. **How did you feel about learning Physics before you started Year 9?**

Robert: Before I started learning Physics I used to study integrated science and I liked it, so I was looking forward to Physics.

Keith: I was excited because it was a new and interesting. I would have liked it if it started in Year 7.

Yuri: I was excited about learning Physics and I was hoping that I would have a teacher that made the lessons fun.

2. **Do you prefer expressing yourself in English or Maltese in class?**

Robert: In Maltese.

Keith: I'm ok with both.

Yuri: Definitely in English.

3. **Does it make any difference to you whether discussions are in Maltese or in English? Why?**

Robert: Now No, not at all. I understand both and the discussions in Physics helped me become more confident with talking in English.

Keith: No it doesn't matter what language we use. I understand and speak both languages.

Yuri: No. I can follow in both languages, but I prefer to share my opinions in English. But as I said before, if students who do not understand Maltese are present in class, I expect the teacher and the students to talk in English.

4. **How do you feel about the type of language used in the Physics classroom? (Do you prefer the teacher to talk in Maltese or in English? Why?**

Robert: I feel good with the teacher using both English and Maltese, but since the exams are in English, I prefer that the teacher explains the important points in English. It helps me know how to say things properly.

Keith: I really don't mind in what language the teacher talks in as I am fluent in both English and Maltese.

Yuri: I honestly don't mind because I know both languages, but if foreigners who do not understand Maltese are present in class I prefer if English is used.

5. **How do you feel about talking/discussing in the Physics classroom?**

Robert: I enjoy them as everyone gets to speak out their opinion and you learn even more if you listen to others' opinions. It is like you add more to what you already know.

Keith: I like them. I learn a lot, because you say something you believe is the right thing, than your friend says something different and you have to think about what you said and what your friend said and try to find out which one is correct. Sometimes you say something and your friends don't understand you, so you have to explain what you had said and while you are explaining it, it makes more sense to you too, so you learn more. You have to focus more so you learn more.

Yuri: I feel confident to tell what I think about something. I find discussion interesting as you say something and you have to say it properly and clearly so your friends can understand you. You talk science.

6. **How do you feel about the scientific language (words/terms which are scientific?)**

Robert: I feel comfortable because once you learn them, then the subject becomes easier.

Keith: I feel that it is important for me to know them as I can understand the questions better and can even write better answers because I use them in my answers.

Yuri: I like to learn and use scientific terminology. It makes me look smarter.

7. **What can you say about the difference between learning Physics using everyday language and then learning the scientific terms or learning Physics using scientific terms only?**

Robert: I understand when we are given a scientific term and the teacher explains it, but I feel that I understood more when we learned Physics using everyday language and then the teacher said what we learned using the scientific terms.

Keith: When during the discussions and activities we used everyday language and then you said what we said in everyday language then you said them in scientific terms, I understood more and remember them well even now and how to use them too.

Yuri: I prefer to learn Physics using everyday language and then learn the scientific terms, because like that, I can really know what they mean and how to use them properly when I am talking about them or writing an experiment or writing my answers to an exam question.

8. **How do you feel about the writing used in Physics classroom (what you write and what the teacher writes)? For example, when doing experiments and writing the conclusions?**

Robert: I feel confident because you write/document what you have done and how you did it. When we did the activities and when we do the experiment, you pay more attention to what you are doing, so you know what you have to write.

Keith: I don't mind writing the conclusions or the lab report, once I know what I have done and why I did it. If I have to just write what the teacher's writes on the board, I find it boring.

Yuri: If I just have to copy what the teacher writes on the board, I don't like it much. But if we carry an experiment and we have to write what we did and the conclusions, I like it. It helps me understand more.

9. **How do you feel when you are doing Physics?**

Robert: I like Physics over any other subject because I like to learn about the things around me and in the past two years, the lessons were fun.

Keith: I enjoy the lesson and I learn more than when we just have to listen.

Yuri: If you are asking me about Physics lessons in general, I feel ok as I like the subject. If you are asking me about when it is us doing something, experiment, discussing in groups, activities, I enjoy them a lot because I learn from my friends and I learn how to explain things properly and how to use scientific terms properly, which makes me feel smarter. I also remember more what we learn when we are doing it, not just listening.

10. **Which type of lessons did you enjoy most? (Discussing as a class, teacher demonstrates an experiment, carrying out an experiment yourself, teacher explains concepts or inquiry activities (like the one of light and prisms and the one of dropping the egg))? Can you explain why?**

Robert: I like the lessons most either when the teacher demonstrates what she is doing because she explains what she is doing and I understand, or when we do activities but the teacher helps us or asks us questions which make us think about how to do it. If we were to do the experiment or the activity without anyone helping us or guiding us it would be harder for us.

Keith: I liked carrying out the experiments myself, the activities and the discussions. My favourite ones were the activities because we shared our ideas, had to think to do it good, we had to plan and test it out, not just sitting down and listen to the teacher.

Yuri: I prefer when we are doing experiments and the activities. I find them more interesting and it will be easier for me to understand the Physics we are doing and to remember it.

11. **How did you feel during your first inquiry activity?**

Robert: I felt excited. We were moving around, we were out of class and not just sitting down. But mostly, because we had never done something like that activity.

Keith: It was exciting. We had to move around, plan how to do it, talk together. We saw how the Physics learned in the classroom applies outside the classroom.

Yuri: I was very excited to do it. We had never done anything like that before. I really enjoyed the lesson.

12. **How do you feel about inquiry activities in the Physics classroom now that you have experience learning through a number of these activities?**

Robert: I feel they are a great way to learn Physics. Every time we did an activity we learned something new.

Keith: I feel that there should be more of them.

Extra question: Can you tell me why?

Keith: I concentrated more. I wanted to get proper conclusions, so I paid more attention, listened and learned from my friends. The Physics we learned from these activities was easier to understand and remember.

Yuri: We didn't have one this year.

Extra question: How do you feel about inquiry activities that you have done such activities for two years?

Yuri: I wish we still do them. It was easier to learn the Physics when you can relate the theory to something in real life. The egg drop activity was not only fun, but it helped us think on what we had learnt about forces and their use in real life, especially when from the effect of dropping an egg from different heights onto different materials, you can understand something big, like the effect of forces during a car accident.

13. **Are there ways in which inquiry activities (Mars Bar, light and prism, egg drop) have helped you to learn Physics?**

Robert: Yes, they helped me a lot because kind of we put the theory to the test ourselves. We did something, and we had to talk about the Physics that was happening. The Physics lessons were different than the lessons of other subjects.

Keith: They have helped me understand Physics more and also how to write things better.

Extra question: What do you mean by write things better?

Keith: When we write the conclusions or we are given a question to explain, I write them as if I am explaining things to someone new in class. So I give a lot of information, easy information and then use the terms we learnt in Physics. Like how you used to do when we told you our conclusions, you said them how we said them and then in physics terms.

Yuri: They helped me explain something which would have been difficult to explain just by trying to visualise what the teacher says. Also, they made it easier to relate the Physics to the real world easier. We got to talk and we build the information together so you remember it more, and the way you asked us questions, helped us think better. You know you used to push us to say things better and explain them, and that has helped me understand that I cannot just say something, I have to say it in a way as if I am explaining it to someone new in class. I think this helped me do better in exams. I learned the technique of giving a proper and detailed answer.

14. **If you had to provide feedback about your experience in the Physics classroom, what would you recommend for effective teaching and learning?**

Robert: I would recommend teaching to be more like the activities and also the discussions we used to do during the last 2 years as they make the lessons more fun and very meaningful.

Keith: To have more discussions and more activities like we did last year and the year before.

Yuri: To have more discussions, more activities and more experiments which we do on our own. And a teacher who loves the subjects and gives the students time to think and talk, not explains and writes on the board just to cover the syllabus or just tells you the right answer when you are stuck.