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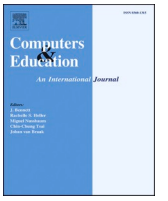

Relations between academic boredom, academic achievement, ICT use, and teacher enthusiasm among adolescents

Francesca Borgonovi [a,*], Magdalena Pokropek [b], Artur Pokropek [c]

[a] UCL Social Science Institute, University College London, London, United Kingdom
[b] University of Warsaw, Krakowskie Przedmieście 26/28, 00-927, Warsaw, Poland
[c] Educational Research Institute (IBE), Górczewska 8, 01-180, Warsaw, Poland

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ABSTRACT

Using large, representative samples (N = 76,818) of 15-year-old students in eight countries that took part in the 2018 edition of the Programme for International Student Assessment (PISA) we develop multilevel regression models to estimate the association between boredom and reading and mathematics achievement and multilevel moderation models to estimate the likelihood that students will experience academic boredom as a function of their use of ICT and how enthusiastic they perceive their teachers to be. Students who reported being bored in mathematics classes had lower mathematics and, in some countries, lower reading achievements than students who did not report being bored in mathematics classes. By contrast, results did not reveal a consistent association between boredom in language and literature classes and during self-study and mathematics and reading achievement. The use of ICT for leisure was associated with a higher likelihood that students reported being bored. By contrast, the use of ICT for learning at home was associated with a lower likelihood that students reported being bored. Students who perceived their teachers to be enthusiastic, whether they used ICT or not, were considerably less likely to report being bored. The association between ICT use and boredom was moderated by teacher enthusiasm. In particular, the use of ICT for leisure was associated with higher boredom among students whose teachers lacked enthusiasm whereas the use of ICT at school was associated with higher boredom among students who perceived their teachers to be very enthusiastic.

1. Introduction

The general public and academic researchers are growing increasingly interested in understanding if the use of information and communication technologies (ICT) influences young people's interest in and engagement with school and learning. In this work, we contribute new evidence to this debate by estimating the extent to which students who are heavy users of ICT report higher levels of boredom. Boredom is an important achievement-related emotion that determines if and how young people engage with learning both in and outside of school. Boredom corresponds to the aversive feeling of wanting but being unable to engage in a satisfying activity (Eastwood, Frischen, Fenske, & Smilek, 2012, p. 483). Although there is no definite consensus on the definition of boredom due to the multidimensionality of this phenomenon (Martin, Sadlo, & Stew, 2006), academic boredom refers to an emotional experience that

* Corresponding author.
E-mail addresses: F.borgonovi@ucl.ac.uk (F. Borgonovi), magdalena.pokropek@uw.edu.pl (M. Pokropek), artur.pokropek@gmail.com (A. Pokropek).

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guides how students interact with peers and teachers in class and influences their learning and achievement (Bench & Lench, 2013; Pekrun, Fren zel, Goetz & Perry, 2007; Ahmed, Van der Werf, Kuyper, & Minnaert, 2013; Pekrun, Hall, Goetz, & Perry, 2014; Tze, Daniels, & Klassen, 2016). Boredom is an important motivational driver, but it has received considerably less attention in educational research than other achievement emotions such as anxiety and enjoyment of learning (Pekrun, Goetz, Titz, & Perry, 2002) and self-rated beliefs such as self-efficacy and self-concept (Bandura, 1997; Eccles & Wigfield, 2002). This is rapidly changing as the literature is increasingly concerned with the study of achievement emotions such as boredom that reflect individuals' perceived experience of ongoing achievement situations (Camacho-Morles et al., 2021).

Boredom motivates action because individuals behave in a particular way to stop being in an unpleasant state. Boredom-induced actions can be trivial or consequential and lead to both positive and negative consequences for individuals experiencing boredom and those around them (Bieleke & Wolff, 2021; Lin & Westgate, 2021; bib_sharp_et_al_2020Sharp, Sharp, & Young, 2020; Wolff, Martarelli, Schüler, & Bieleke, 2020).

Academic boredom is boredom experienced by students in schools and while they complete academic tasks (Acee et al., 2010). Psychological research suggests that adolescents are very likely to describe themselves as being bored, to experience academic boredom, and to consider schools as especially boring, leading some to disengage and, at the extreme, drop out (Grazia, Mameli, & Molinari, 2021; Respondek, Seufert, Stupnisky, & Nett, 2017; Wegner, Flisher, Chikobvu, Lombard, & King, 2008).

The literature distinguishes between trait boredom – defined as the propensity different individuals have to experience boredom when they are in a given situation – and state boredom – defined as the propensity of different situations to elicit boredom (Westgate & Wilson, 2018). Personality traits, temperament, non-cognitive factors as well as situational appraisals (such as how much students value and feel in control in classroom settings) determine the likelihood that different students will experience academic boredom (Daschmann, Goetz, & Stupnisky, 2011; Pekrun, 2006). Examples of situational determinants of academic boredom include the quality of classroom instruction, whether teachers use a variety of teaching methods, how enthusiastic teachers are, if they adapt their teaching to the demands of their students' academic potential, and the relevance of academic material for the needs and expectations of students (Daschmann et al., 2011).

Building on research highlighting the role of situational factors in determining academic boredom, some educators have advocated a greater use of digital technologies in instructional settings to promote academic motivation, engagement, and reduce boredom (Cheng, Wang, & Yu, 2022; Cortázar et al., 2021; Krath, Schürmann, & von Korflesch, 2021; Kyriazopoulos, Koutromanos, Voudouri, & Galani, 2022; Martínez-Borreguero, Perera-Villalba, Mateos-Nunez, & Naranjo-Correa, 2020; Reeves, Crippen, & McCray, 2021; Reich, 2020). Others have promoted the adoption of some of the principles underpinning play in general and video games in classrooms (Greipl et al., 2021; Király et al., 2020; Shapiro, 2019).

However, it has been suggested that the high level of use of digital technologies by today's children outside of classroom settings may be precisely what determines their inability or unwillingness to engage with learning in academic settings (Aziz & Yong, 2019). For example, prior evidence on the association between boredom and ICT use highlights that children who use smartphones compulsively are more likely to report being bored (Ksinan, Mališ, & Vazsonyi, 2021). A t the same time, given the correlational nature of the evidence, children who are bored may use smartphones and other digital devices to alleviate their boredom (Finkielsztein, 2020; Panova & Lleras, 2016).

We use new, unique data from eight countries (Bulgaria, Georgia, Hong Kong, Ireland, Mexico, Panama, Serbia and Spain) that participated in the 2018 edition of the Programme for International Student Assessment (PISA) to provide robust and generalizable evidence on the specific association between boredom in academic settings and academic achievement; and between different forms of ICT use, boredom in academic settings, and teacher characteristics. More specifically we: 1) map academic boredom among large, representative samples of 15-year-old students; 2) detail the association between academic boredom and academic achievement in reading and mathematics; 3) examine if students who make extensive use of ICT for leisure and for learning both at school and at home are more likely to express being bored in class and during self-study at home than students with little or no ICT use; and 4) consider if teachers' enthusiasm moderates the association between ICT use and boredom.

2. Review of the literature

According to the control-value theory of achievement emotions (Pekrun, 2006) boredom, like other achievement emotions, depends on: the extent to which students feel in control over achievement activities, the outcomes such activities entail (for example if students feel that they can study hard for a test and that performing well on such test depends on their effort) (Perry, Hladkyj, Pekrun, & Pelletier, 2001), and the degree to which students value these activities and outcomes (i.e. how much they care about doing well on the test) (Pekrun, 2006). Therefore, individuals can be expected to experience boredom depending on how much control they feel they have over achievement activities and the value they place on such activities and resulting outcomes. Crucially, the control-value theory of achievement emotions defines a cognitive-motivational mediation model according to which achievement emotions such as boredom influence academic engagement and achievement. The theory also posits that such influence is mediated by a series of cognitive, motivational, and self-regulatory processes that are critical for success in academic settings. These include interest, cognitive resources, effort regulation, and, crucially for this work, the use of and exposure to different learning strategies, opportunities, and different environments (Pekrun, 2006, 2018).

Boredom is a multidimensional achievement-related emotion that has complex cognitive, affective, motivational, and behavioral determinants and consequences. Environmental theories of boredom, functional theories of boredom, and attentional theories of boredom are some of the key theoretical perspectives that have considered in-depth what factors shape the likelihood that individuals will experience boredom. Each theoretical perspective illuminates key determinants of boredom and the mechanisms that could

explain how and why ICT use and teachers' enthusiasm could shape the likelihood that 15-year-olds will experience this achievement-related emotion in academic settings.

Environmental theories of boredom stress that when environments constrain individuals' actions and autonomy (Chin, Markey, Bhargava, Kassam, & Loewenstein, 2017) they increase the likelihood that individuals will experience boredom (Ohlmeier, Finkielsztein, & Pfaff, 2020). Functional theories of boredom stress the importance for individuals to engage in activities that they find meaningful (Tam, Van Tilburg, Chan, Igou, & Lau, 2021). According to functional theories, boredom renders salient the opportunity cost of one's time by signalling to the individual that continuing to engage with a given situation does not maximize psychological well-being compared to alternative uses of time (Bench & Lench, 2013; Kurzban, Duckworth, Kable, & Myers, 2013). As a result, when individuals find themselves in situations that they feel have little meaning to them or for which attractive alternatives are available, they are more likely to perceive the situation or task they are currently engaged in as boring. Attentional theories of boredom emphasize the role of individuals' capacity to regulate attention as a key cognitive process determining the experience of boredom (Eastwood et al., 2012; Hunter & Eastwood, 2018). According to attentional theories, boredom results from the failure of the individual to orient, engage, and maintain focus on an activity. Attention is a limited cognitive resource that enables individuals to selectively filter information and prioritize some pieces of information while ignoring others (Carrasco, 2011).

2.1. The experience of boredom in academic settings

Environmental, functional, and attentional theories of boredom lead to different predictions over relative feelings of boredom while engaging in different academic activities – such as being in class in school and engaging in self-study at home – and while engaging in academic activities rather than non-academic activities – such as spending time with friends.

Environmental theories of boredom predict that students will be less likely to find self-study at home boring than participation in classes because during self-study they have greater autonomy over how they organize their time. Schooling is compulsory until a certain age and during compulsory schooling, students typically have little autonomy over whether they are in class, what they learn and how. External authorities, school principals or teachers often define curricula, adopt textbooks and organize classroom activities (Jeong & Luschei, 2018; OECD, 2020a). Although in many countries students and their families can choose or are directed to different educational programs at the secondary level depending on their interests and ability, day-to-day instruction is mostly beyond students' control (OECD, 2019b; OECD, 2020a; Vosniadou, 2020). Moreover, peer interactions in classroom settings are generally directed by teachers. All these factors could potentially lead to low levels of sense of control and autonomy in classroom settings (van Leeuwen & Janssen, 2019).

By contrast, attentional and functional theories of boredom lead to the prediction that self-study at home could be perceived as an especially boring academic activity by students because self-study is a context in which exercising attention and cognitive control may be more difficult and the salience of alternative uses of time is higher than spending time in class. Students have many potential distractors around them during self-study at home and at the same time they have little external control and supervision. Furthermore, while in class the only alternative to engagement is disengagement, at home, during self-study, students can engage in a wealth of alternative activities.

Both environmental and functional theories of boredom lead to the prediction that teenage students will experience higher levels of boredom while engaging in academic activities – such as spending time in language and literature classes, mathematics classes, and self-study at home – than when spending time with friends. Spending time with friends is an activity in which most teenagers are likely to experience feelings of control and meaning. Nonetheless, some students may be unable to appropriately handle the free time they have at their disposal or have salient alternative uses of time, thus experiencing feelings of leisure boredom (Leung, 2020). Leisure boredom has been defined as 'the subjective perception that available leisure experiences are not sufficient to instrumentally satisfy needs for optimal arousal' (Iso-Ahola & Weissinger, 1990). The literature indicates that adolescents experiencing leisure boredom may be at an especially high risk of engaging in risky behaviors (Iso-Ahola & Crowley, 1991; Wegner & Flisher, 2009).

2.2. The relationship between boredom and academic achievement

The literature detailing the association between academic boredom and academic achievement has increased in recent years (Camacho-Morles et al., 2021). Such research generally indicates that boredom is negatively associated with academic achievement in language and literature (Fritea & Fritea, 2013) and in mathematics (Ahmed et al., 2013) and that the association between academic boredom and achievement is reciprocal (Tze et al., 2016). Low achievers are more likely to feel bored but oftentimes when students feel bored, their achievement suffers. Academic boredom could lead to poorer academic results if it undermines attention, effort, motivation, and engagement during educational activities such as participation in class and self-study (Camacho-Morles et al., 2021). However, at the same time, academic boredom could lead to more positive academic results over time whenever boredom leads students to engage in self-reflection and improved study habits (Bench & Lench, 2013; Mann & Cadman, 2014).

2.3. The relationship between ICT use and academic boredom

The childhood and the teenage years are characterized by significant emotional and cognitive development and, as such, are highly susceptible to external stimuli that could influence perceptions of control, value over achievement activities, and ability to direct attention (DiPietro, 2000; Fuhrmann, Knoll, & Blakemore, 2015). The importance of the early years for emotional and cognitive development has led to concerns both in academic research as well as the popular media about the extent to which the use of different

technologies in childhood and adolescence may have a lasting impact on brain development, social, emotional, and cognitive functioning (Alter, 2017; Carr, 2011; Greenfield, 2003, 2015; Orben & Przybylski, 2019; Turkle, 2011). As more children access digital technologies sooner (Chaudron, Di Gioia, & Gemo, 2018; Hooft Graafland, 2018), engage in a greater variety of activities using such technologies and in different contexts (Borgonovi & Pokropek, 2021; Ofcom, 2020) the perceived importance of understanding the effects of technology use grows and guidelines designed to reduce harm and promote benefits proliferate (Straker, Harris, Joosten, & Howie, 2018).

Recent reviews suggest that the impact of ICT use on attention and cognitive control varies depending on: users' characteristics, the form digital technologies take, the circumstances in which use occurs, and the interaction between the three factors (Vedechkina & Borgonovi, 2021). In particular, research suggests that very high levels of ICT use and use that occurs at times that disrupt sleep, are associated with attention and cognitive control disturbances (Vedechkina & Borgonovi, 2021). A potentially problematic use of ICT is more likely to occur when ICT is used for leisure. ICT use for leisure could therefore shape how prone individuals are to experience situations marked by lack of control as boring, and to perceive academic activities as less meaningful because the value associated with alternative uses of time – such as engaging with ICT – is considered to be higher.

Commercial digital services and products that youngsters use during their leisure time are adaptable and are designed so that they adjust to satisfy the specific needs of individuals, thus tailoring the level of stimulation to the moment-by-moment requirements of different users (Liu, 2005). As a result, ICT products and services used by adolescents in their leisure time maximize engagement, sense of control and meaning (Huang, Ali, & Liao, 2017; Liu, 2005; Petko, Schmid, & Cantieni, 2020). An extensive use of ICT for leisure may therefore lead individuals to develop aversive reactions to being in situations where they lack control. Moreover, individuals who make extensive use of ICT in their free time may have personalities that lead them to find a state of lack of autonomy as especially aversive.

Attention could be a key mechanism through which digital technologies can interact with broader cognition because young ICT users are often heavy practitioners of digital multitasking due to the portability and integration of digital applications (Anderson & Jiang, 2018; Vedechkina & Borgonovi, 2021; Ettinger & Cohen, 2020). Frequent digital multitasking may lead to increased feelings of boredom because it might interfere with the development of attention networks and executive functions, resulting in attention difficulties and a susceptibility to frequent task switching over sustained attention (Fox, Rosen, & Crawford, 2009; Levine, Waite, & Bowman, 2007). At the same time, it has been suggested that the early exposure and constant access to technology by today's youth has led them to acquire familiarity with technology and multitasking proficiency, thus reducing negative consequences on attention associated with ICT use (Kirschner & De Bruyckere, 2017; Prensky, 2001). Furthermore, the integration of ICT in academic settings could shape students' level of perceived control and sense of agency in school by allowing students to engage in academic activities through a medium in which they feel familiar and in control to orient, engage, and maintain focus and attention. The use of ICT in classrooms may also be an expression of the willingness of teachers to create learning environments that better match students' expectations and preferences, thus giving them a higher sense of control and meaning.

The increase in the availability of digital technologies and diversification of devices and applications, coupled with the recognition that mastering such technologies can be used to promote learning and to engage children with school (Greipl et al., 2021; Olszewski & Crompton, 2020; Shapiro, 2019) prompted many educators to promote the use of ICT in schools (Krath et al., 2021; Redecker & Punie, 2017). The adoption of features typical of videogames or other ICT applications for learning both in classrooms and for self-study was thought of as a way to increase interest, making learning more enjoyable and meaningful for students (Prensky, 2001). It is possible that the use of ICT for learning, whether in school or at home for self-study, allows educators to better tailor material to the learning needs of their students and for students to adjust the pace, content, and style to their needs. This, in turn, could improve the sense of control and meaning students experience when engaging in academic activities using digital learning aids relative to alternative paper-based aids. Finally, it is possible that educators who promote the use of ICT for learning may be especially concerned about engagement, motivation and boredom among their students and might implement a range of strategies to engage their students, give them a sense of agency over their learning and make such learning meaningful to them.

2.4. The relationship between teacher enthusiasm and academic boredom

In line with predictions of control-value theory of achievement emotions, the literature on the antecedents of academic boredom suggests that school climate and teachers' attitudes play a key role in alleviating academic boredom since these factors determine students' sense of control and meaning at school (Daschmann, Goetz, & Stupnisky, 2014; Goetz, Lüdtke, Nett, Keller, & Lipnevich, 2013; Tam et al., 2020). Students' perceptions of teacher enthusiasm are especially strongly associated with their self-reported boredom in academic settings (Cui, Yao, & Zhang, 2017; Keller, Hoy, Goetz & Frenzel, 2016). Teachers and educators are also key to ensure that students are able to orient, engage, and maintain focus on academic activities. The literature suggests that students have more positive attitudes towards learning when they have teachers who are enthusiastic and display such enthusiasm in class (Keller, Hoy, Goetz, & Frenzel, 2016; Lazarides, Gaspard, & Dicke, 2019). Teachers' enthusiasm is also linked to lower levels of academic boredom (Goetz et al., 2013; Tam et al., 2020). Enthusiastic teachers have students who are more motivated and inspired (Keller, Goetz, Becker, Morger, & Hensley, 2014; Kunter et al., 2013; Moè, 2016; Patrick, Hisley, & Kempler, 2000). They are able to retain students' attention (Keller, Neumann, & Fischer, 2012), transmit positive feelings towards academic subjects (Hatfield, Cacioppo, & Rapson, 1993) and lead students to spend more time on learning tasks (Brigham, Scruggs, & Mastropieri, 1992). Students perceive their teachers to be enthusiastic when teachers' emotions give rise to a range of behaviors – such as gestures, body movements, facial expressions and voice intonations – that communicate a strong interest in the subject they are teaching and/or passion for the act of teaching (Kunter et al., 2013). In qualitative studies, teachers describe that students' emotional state in the classroom depends on the level of enthusiasm they bring to their teaching (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009).

Teacher's enthusiasm as a driver of engagement and attention could be especially important for those students who are most likely to be unable to devote adequate attention to the task (Keller et al., 2014; Marzano & Pickering, 2010), who have a low sense of control over their learning (Lazarides et al., 2019) and who find learning not meaningful for their present and future (Lazarides, Buchholz, & Rubach, 2018). Teacher enthusiasm could therefore be a key moderator of the association between ICT use and boredom in class and during self-study at home if students who are heavy users of ICT are more likely to struggle with engagement (Nikolopoulou, 2020; Stieler-Hunt & Jones, 2015). At the same time, to the extent that ICT devices are worse at motivating students than enthusiastic teachers, it is possible that when students have enthusiastic teachers, a higher use of ICT use at school may be associated with higher boredom whereas with teachers who are not enthusiastic a higher use of ICT use at school may be associated with lower boredom.

3. Research questions

Based on the review of the literature and empirical evidence detailed in the previous section, we develop analyses to answer six research questions. By comparing students in countries that differ in terms of level of economic development, culture, prevalence of ICT use and the organization of schooling (OECD, 2020a), we aim to establish similarity across countries in overall levels of boredom, in the associations between boredom and academic achievement, and in the associations between ICT use and boredom.

RQ1. Do 15-year-old students report higher levels of boredom while engaging in language and literature classes, mathematics classes, and during self-study at home or when spending time with friends?

RQ2. Is academic achievement in reading and mathematics associated with whether 15-year-old students report being bored while engaging in language and literature classes, mathematics classes, and during self-study at home?

RQ3. Is the use of ICT for leisure associated with a higher likelihood that 15-year-old students will report higher levels of boredom while engaging in language and literature classes, mathematics classes, and during self-study at home?

RQ4. Is the use of ICT for learning at school and at home associated with the likelihood that 15-year-old students will report higher levels of boredom while engaging in language and literature classes, mathematics classes, and during self-study at home?

RQ5. Are students who perceive their teachers to be enthusiastic less likely to report being bored in class and during self-study?

RQ6. Does teacher enthusiasm moderate the association between ICT use and the likelihood that 15-year-old students will report higher levels of boredom in class and during self-study?

4. Data and methods

4.1. Programme for International Student Assessment (PISA)

PISA is a low-stake international large-scale assessment that has been administered to samples of 15-year-old students every three years since 2000. PISA involves large, representative samples of students from countries that vary widely in cultural, linguistic and social background, level of economic development, technological adoption and in how the education system is organized. The core PISA instruments are a cognitive test and a background questionnaire. Our study makes use of the well-being and the ICT familiarity questionnaires, two optional questionnaires that were implemented in 2018 and which contain information on boredom (well-being questionnaire) and ICT use (ICT familiarity questionnaire). Our analyses are based on data from the eight countries participating in PISA 2018 that administered both questionnaires. Because these countries are not representative of the full set of countries participating in PISA, estimates should not be considered to reflect associations beyond the countries considered. The low number of countries included in analyses also means that it is not possible in this work to study how the organization of education systems may be associated with the prevalence of academic boredom. At the same time, since most existing research on academic boredom is based on studies conducted in the United States, United Kingdom, and Germany (Daschmann et al., 2011; Sharp et al., 2020; Vodanovich & Watt, 2016) our work considerably broadens the evidence on academic boredom among schooled populations.

Over the years, PISA has been widely used in academic research and has also been very influential in shaping education policy and benchmarking efforts at the international level (Hopfenbeck et al., 2018) although it has been criticized for its influence on policy-making (Meyer & Benavot, 2013; Zhao, 2020) and the fact that reports and research based on PISA data often do not adequately describe its assumptions and limitations (Rutkowski & Rutkowski, 2016). Notwithstanding the criticism, PISA is the best data source to examine our research questions. Furthermore, many of the critics of PISA do not argue against its use in well-defined empirical research but, rather, to the very large role country rankings based on PISA have as a guide of education policy.

4.2. Participants

Our data come from the 2018 edition of PISA. All cases used in our analyses were extracted from the public-use files, which can be downloaded from: http://www.oecd.org/pisa/data. Weighted samples are representative of students who were enrolled in grade 7 or above and were between 15 years and 3 months and 16 years and 2 months at the time of the administration (generally referred to as 15-year-olds in this work). In each cycle, PISA test-takers are selected from the population of 15-year-old students in each participating country according to a two-stage random sampling procedure. The PISA technical standards require that in a first stage, a stratified sample of schools is drawn and that, in a second stage, students are selected at random in each sampled school. Our analytic sample

includes a total of 76,818 students.

4.3. Instruments

Participants first took part in the timed, 2-h PISA test. After a short break they completed the core background questionnaire that was administered in all countries followed by the ICT and the well-being questionnaires. Both the test and the questionnaires were administered on computers. The key assessment domains in PISA are reading, mathematics and science. Reading was the main assessment domain in 2018, with a smaller set of questions being administered in mathematics and science. In this work we only consider students' achievement in reading and mathematics since there were no questions on boredom in science classes and in the analyses we match boredom in language and literature classes and boredom in mathematics with achievement in the relevant academic domains, namely reading and mathematics.

Because reading was the main assessment domain in 2018, in the students were asked detailed questions on their engagement with reading, reading activities they did in school and interactions with the teacher responsible for courses in language and literature. We exploit the detailed questions on students' reports of their teachers' behaviors in language and literature classes to consider the extent to which teacher practices can moderate the association between ICT use and academic boredom by focusing on students' boredom in language and literature classes.

The core student questionnaire captured students' demographic and socio-economic characteristics, general attitudes towards learning, as well as information about their school, peers and teachers. The ICT questionnaire was designed to identify in-depth students' use of ICT devices, both for learning and for leisure. The well-being questionnaire was designed so that students could describe the state of their physical and psychological health and general outlook to life in school and beyond.

Table 1
Items used to construct the ICT use and teacher characteristics indicators.

Key independent variables	Response categories on frequency	Response categories on activities and situations
ICT use		
ICT use for leisure	(1) Never or hardly ever; (2) once or twice a month; (3) one or twice a week; (4) every day or almost every day	(1) playing one-player games; (2) playing collaborative online games; (3) using e-mail; (4) chatting online; (5) browsing the internet for fun; (6) downloading music, films, games or software from the Internet
ICT use for learning at home (activities)	(1) Never or hardly ever; (2) once or twice a month; (3) one or twice a week; (4) every day or almost every day	(1) browsing the Internet for schoolwork (e.g. preparing an essay or presentation); (2) using e-mail for communication with other students about schoolwork; (3) using e-mail for communication with teachers and submission of homework or other schoolwork; (4) downloading, uploading or browsing material from your school's website (e.g. time table or course materials); (5) check the school's website for announcements, e.g. absence of teachers; (6) doing homework on a computer
ICT use for learning at school (activities)	(1) Never or hardly ever; (2) once or twice a month; (3) one or twice a week; (4) every day or almost every day	(1) chatting on line at school; (2) using e-mail at school; (3) browsing the Internet for schoolwork; (4) downloading, uploading or browsing material from the school's website; (5) posting your work on the school's website; (6) playing simulations at school; (7) practicing and drilling, such as for foreign language learning or mathematics; (8) doing individual homework on a school computer; (9) using school computers for group work and communication with other students
ICT use for learning at school (subjects)	(1) No time; (2) 1–30 min a week; (3) 31–60 min a week; (4) more than 60 min a week	Academic subjects for which digital devices are used in a typical week: (1) language and literature lessons; (2) mathematics; (3) science; (4) foreign language; and (5) social sciences classes
ICT use for learning at home (subjects)	(1) No time; (2) 1–30 min a week; (3) 31–60 min a week; (4) more than 60 min a week	Academic subjects for which digital devices are used in a typical week: (1) language and literature lessons; (2) mathematics; (3) science; (4) foreign language; and (5) social sciences classes
Teacher's characteristics		
Teachers' enthusiasm	(1) strongly disagree; (2) disagree; (3) agree; (4) strongly agree	(1) It was clear to me that the teacher liked teaching us; (2) the enthusiasm of the teacher inspired me; (3) it was clear that the teacher likes to deal with the topic of the lesson; (4) the teacher showed enjoyment in teaching
Disciplinary climate	(1) every lesson; (2) most lessons; (3); some lessons; (4) never or hardly ever	(1) students don't listen to what the teacher says; (2) there is noise and disorder; (3) the teacher has to wait a long time for students to quiet down; (4) students cannot work well; (5) students don't start working for a long time after the lesson begins
Teacher support	(1) every lesson; (2) most lessons; (3); some lessons; (4) never or hardly ever	(1) the teacher shows an interest in every student's learning; (2) the teacher gives extra help when students need it; (3) the teacher helps students with their learning; (4) the teacher continues teaching until the students understand
Teachers' stimulation of reading engagement	(1) every lesson; (2) most lessons; (3); some lessons; (4) never or hardly ever	(1) the teacher encourages students to express their opinion about a text; (2) the teacher helps students relate the stories they read to their lives; (3) the teacher shows students how the information in texts builds on what they already know; (4) the teacher poses questions that motivate students to participate actively

4.4. Variable descriptions

4.4.1. Dependent variables

Our key dependent variables are students' self-reported boredom during language and literature classes, mathematics classes, and during homework or self-study at home. In the first part of the study, we compare levels of self-reported boredom in academic settings with students' self-reported boredom when spending time with friends. Students were asked to report how bored they were during the last time they engaged in these activities and indicate if they felt bored 'not at all', 'a little', 'quite a bit' to 'extremely'.

4.4.2. ICT use

Our five key independent variables indicating students' use of ICT are: students' use of ICT for leisure, ICT use for learning at home (activities), ICT use for learning at home (subjects), ICT use for learning at school (activities), and ICT use for learning at school (subjects).

Table 1 illustrates the specific items that were used to construct the five indicators of ICT use in PISA 2018. Students were asked to report the frequency with which they engaged in a range of ICT-related activities or to report the frequency with which they used ICT to study different academic subjects. The reliability coefficients for all composed scales used in this paper are presented in Table A15 in the Supplementary Online Annex. All ICT use indices were rescaled so that each had a mean of 0 and a SD of 1 across OECD countries and higher values indicated more frequent use of more devices for more activities (see Table 2).

4.4.3. Teacher enthusiasm and other teacher-related factors

Students participating in PISA were asked to report the attitudes of their language and literature classes teachers, the climate in classes led by these teachers and the pedagogical approaches used by these teachers. Because the PISA design is not classroom based, students in the same school could have different teachers. Thus, we cannot know if students in a school report different levels of enthusiasm among their teachers because they have different teachers or because they have different perceptions of the same teacher. Table 1 details the items used for the construction of the indices reflecting teacher's enthusiasm; teacher support, teachers' stimulation of reading engagement and disciplinary climate. All teacher indices were rescaled so that each has a mean of 0 and a standard deviation of 1 across OECD countries and higher values indicate more positive environments. The literature indicates that students are more engaged in school in the presence of a positive school climate (Thapa, Cohen, Guffey, & Higgins-D'Alessandro, 2013). Therefore, in order to reduce omitted variable bias and estimate the association between teachers' enthusiasm and students' boredom and the moderating role of teachers' enthusiasm when estimating the association between students' use of ICT and boredom we control for potential confounders that characterize other contextual characteristics of classroom climate and teacher practices.

4.4.4. Academic achievement

As indicators of academic achievement, we use the PISA reading and mathematics scores, matching the achievement domain to the relevant boredom indicator. Reading achievement is also introduced as a control for boredom during self-study at home. PISA test scores are included in the PISA datasets as multiple imputed measures of proficiency ("plausible values"). PISA test scores are based on item-response-theory scaling procedures and are comparable across students taking different test forms (OECD, 2017). In 2018 a set of 10 plausible values were reported. We rescale the PISA reading and mathematics achievement scales so that each has a mean of 0 and a standard deviation of 1 across countries in our sample. Data on reading proficiency are not available for Spain because despite meeting technical standards some reading data for Spain displayed implausible response behavior and therefore the OECD decided not to report reading proficiency for Spain (OECD, 2019c, p. 208).

Table 2
Sample descriptive statistics in eight countries.

Variables	mean	sd	min	max	count	% Missing
Math achievement	448.05	106.29	64.31	860.19	76,818	0
Reading achievement	440.98	107.95	119.72	823.46	41,323	46.2 (Spain)
Boredom in math classes	2.18	0.98	1.00	4.00	57,033	25.8
Boredom in language	2.04	0.96	1.00	4.00	56,426	26.5
Boredom during self-study	2.24	0.99	1.00	4.00	52,827	31.2
% of females	0.49	0.50	0.00	1.00	76,818	0
Economic, social and cultural status	−0.45	1.13	−7.01	4.21	76,312	0.7
Parents' emotional support	−0.08	1.01	−2.45	1.03	58,453	23.9
ICT use for leisure	−0.01	1.17	−3.59	4.25	65,497	14.7
ICT use for learning at home (activities)	0.07	1.09	−2.30	3.31	61,610	19.8
ICT use for learning at school (activities)	−0.07	1.09	−1.72	3.30	59,634	22.4
ICT use for learning at home (subjects)	−0.06	1.05	−1.30	2.50	64,936	15.5
ICT use for learning at school (subjects)	−0.31	0.95	−1.22	2.44	66,803	13
Perceived teacher's enthusiasm	0.11	0.99	−2.22	1.82	74,489	3
Disciplinary climate (language lessons)	0.04	1.08	−2.71	2.03	75,242	2.1
Teacher support (language lessons)	0.17	0.99	−2.74	1.34	75,210	2.1
Stimulation of reading engagement	0.07	1.04	−2.30	2.09	74,132	3.5
Observations	76,818					

4.4.5. Controls

In all models we control for gender, socio-economic status, academic achievement, parents' emotional support and teachers' enthusiasm. In order to explore the role of teacher practices in shaping the association between ICTuse and boredom in language and literature classes, we further control for teachers' stimulation of reading engagement, teachers' support in test language lessons and disciplinary climate in test language lessons.

We control for gender because the literature indicates that girls tend to be more motivated and more engaged at school (Symonds, D'Urso, & Schoon, 2023; Bang, Won, & Park, 2020) and boys and girls have different patterns of ICT use (Vedechkina & Borgonovi, 2021). Gender was reported by students in the background questionnaire and we report differences in outcomes associated with being a girl. We control for socio-economic status because children from a disadvantaged socio-economic status are more likely, other things being equal, to be disengaged from school than their more advantaged peers (Tomaszewski, Xiang, & Western, 2020), to have lower levels of motivation (Suárez-Álvarez et al., 2014) and, because of their lower cultural capital, are often treated differently from their more advantaged peers by their teachers (Scales, Van Boekel, Pekel, Syvertsen, & Roehlkepartain, 2020). There is no evidence of major differences across socio-economic groups in ICT use (Huang, Jiang, Yin, & Jong, 2021). We control for socio-economic condition through the PISA index of economic, social and cultural status (ESCS). The ESCS index is an aggregate indicator that reflects the economic, social and cultural status of students and is based on students' answers to items in the PISA background questionnaire asking them to report the educational attainment of their parents, their occupation and the availability of a range of resources within their home (OECD, 2017). The index is standardized to have a mean of 0 and a standard deviation of 1 on average across OECD countries.

Estimated associations could reflect differences across children in household environment, an important determinant of students' attitudes towards school and learning (Browman, Svoboda, & Destin, 2022) and ICT use both for leisure and for learning because of home cultural and final resources, supervision, and school selection (Becker, 2022). In order to control for the extent to which parents provided emotional support to their children, which could shape both the likelihood that they will express boredom and use ICT, we include an index constructed using students' responses on a four-point Likert scale ranging from 'strongly disagree', to 'strongly agree' to the following statements: 'my parents support my educational efforts and achievements'; 'my parents support me when I am facing difficulties at school'; and 'my parents encourage me to be confident' (OECD, 2020b). Students' reports were combined to create the index of parents' emotional support, which has a mean of 0 and a standard deviation of 1 across OECD countries.

4.5. Modelling

In a first step we used multiple imputations using Markov Chain Monte Carlo (MCMC) procedures to account for missing data in PISA. MCMC assumes that all variables in the imputation model have a joint multivariate normal distribution. This method is robust to the violation of the multivariate normality (MVN) assumption, especially when estimates are conducted using large samples (Demirtas, Freels, & Yucel, 2008; Lee, 2000). We performed multiple imputations using all variables using in the modelling stage. We generated ten imputation sets and paired each of these ten with one plausible value of achievement in PISA (plausible values are essentially imputed values of the likely ability of respondents in PISA based on their response patterns in the PISA test and are provided by the OECD in the publicly released PISA dataset) (Mislevy, Beaton, Kaplan, & Sheehan, 1992). Information about efficiency and further details on imputation results are presented in Table A3 in the Supplementary Online Annex. These results suggest that multiple imputation models had high levels of efficiency given the set of variables used in the imputation procedure.

In a second step we performed multilevel models on multiple imputed datasets, in which students were considered as the first-level units and schools were considered as the second-level units. We employed multilevel modelling to take into account the nested nature of the PISA data, in which several students attend the same school. In PISA, schools are the primary sampling unit, and within sampled schools, a random sample of students from each selected school is then retained. We computed Intra Class Correlation (ICC) coefficients for all dependent variables, and in many cases, these were higher than .1, which the literature identifies as a threshold above which the use of multilevel modeling is suggested (Hox, 2010; Lee, 2000). All our independent variables except for gender are continuous. All continuous variables were grand mean-centred (as recommended by Hox, 2010; Hofmann & Gavin, 1998; Mathieu & Taylor, 2007). The gender variable was coded as a binary indicator where one denotes females. All estimates of multilevel models were conducted using the imputed datasets (see first step). This involved fitting ten sets of multilevel models, each with one plausible value and imputed values for missing data, and then combining these values using the Rubin rule (Little & Rubin, 1987) as per OECD recommendations.

We estimated three sets of multilevel models to answer different research questions.

Set of models 1) To estimate the association between academic achievement and academic boredom, we fit two multilevel models on each of the countries in our sample to identify associations between boredom during mathematics classes, language and literature classes, and during self-study at home and achievement in mathematics and between boredom during mathematics classes, language and literature classes and during self-study at home and achievement in reading. Key controls in these models are gender and socio-economic condition.

Set of models 2) To estimate the association between ICT use and boredom, we fit a series of linear multilevel models on each of the eight-country samples. Although our dependent variables defining boredom are represented on a 4-point Likert-type scale, linear models give a good approximation of true relations between investigated variables. Simulation studies indicate that the potential biases in linear models are of little practical importance (Hellevik, 2009) and, contrary to non-linear models for categorical outcomes, linear models are much easier to interpret, especially when interaction terms are investigated (Ai & Norton, 2003). Furthermore, they do not imply problems with cross-group comparability. Ordered logistic regressions suffer from unobserved heterogeneity even when omitted variables are unrelated to the independent variables included in the model. As a result, it is problematic to compare estimates

in nonlinear models such as ordered logistic regressions across samples and groups within samples, as is the case in our work, because unobserved heterogeneity can vary across the samples and groups (Long, 2008; Mood, 2010). Linear models do not suffer from the same shortcomings and are therefore preferable when modelling non-extreme probabilities, which is the case in our work. We present key standardized coefficients of interest together with 95% confidence intervals estimated using linear models in figures in the main body of the manuscript and full results in Tables in the Supplementary Online Annex.

Set of models 3) In order to identify the moderating effect of teacher enthusiasm on the association between ICT use and boredom, we develop a series of interaction models on the pooled sample of countries, adding country-fixed effects as well as the interaction between teacher enthusiasm and the indicators of ICT use for leisure and for learning. In these models we focus on the two indicators of ICT use for learning at home and at school that were strongly associated with boredom in previous analyses, namely the indicator of ICT use for learning at home (activities) and the indicator of ICT use for learning at school (subjects). We also added quadratic terms for explanatory variables to prevent spurious interaction effects. We present results using marginal effects, which were calculated using predictions of the previously fit models, fixing covariates presented in the graphs at specific values and the average value of the remaining controls (Williams, 2012). Marginal effects can be assimilated into a graphical representation of regression coefficients from multivariate models, allowing for an easier and more intuitive interpretation of results. Graphical representations of marginal effects (Royston, 2013) are based on predictions for arbitrary cut points (on standardized variables −3, −1.5, 0, 1.5, 3). To facilitate the interpretation of interaction effects, we also present results using Johnson-Neyman plots.

All effects presented in the main paper are statistically significant ($p < -0.05$) and exact regression coefficients showing the standardized effects of continuous variables as well as associated standard errors, can be found in the Supplementary Online Annex. We chose a p-value of .05 in the main text despite the fact that we have a considerable sample size at the student level because only around 150–200 schools were sampled in each country (except for Spain, where over 1000 schools were sampled to obtain representative results at the sub-national level). Standard errors account for the lack of independence between students attending the same school. We present country-specific results of interactions in Table A17 and Figure A1 in the Supplementary Online Annex.

We tested the normality and multicollinearity of the variables used in all models as well as homoscedasticity. For multi-collinearity, we calculated the variance inflation factor (VIF). The mean VIF of our analyses was 1.31 and never reached the threshold value of 3, therefore lending support to our analyses. We tested normality and homoscedasticity by visually inspecting diagnostic plots and did not observe strong deviations from the normality and homoscedasticity assumptions. All analyses were conducted using the software

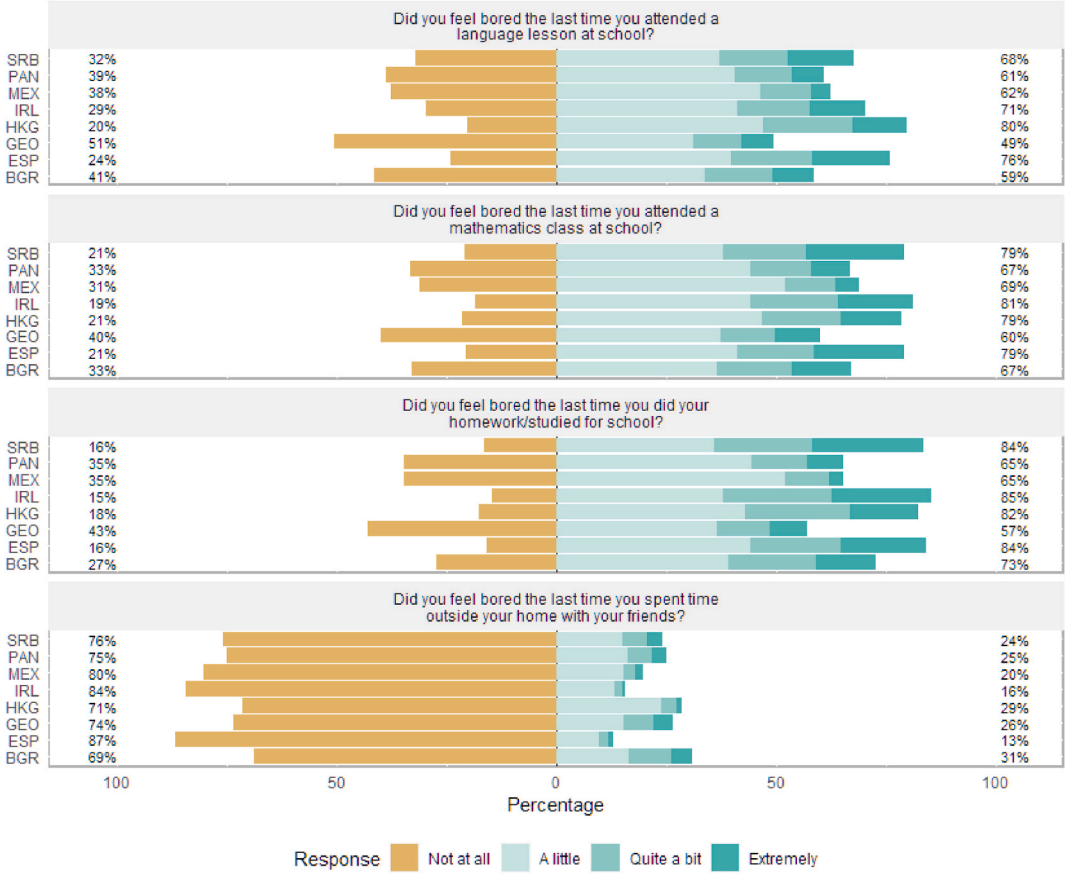

Fig. 1. Levels of boredom in eight countries.

Stata version 17.0.

5. Results

5.1. Levels of academic boredom

Fig. 1 allows us to answer RQ1 by illustrating the percentage of students who report being not at all, a little, quite a bit, and extremely bored in their last language and literature class at school, in their last mathematics class at school, when they last did their homework or studied for school, and when they last spent time outside with their friends.

Analyses presented in Fig. 1 reveal that across all the countries in our sample, regardless of differences in their education system characteristics (OECD, 2020a) or other underlying economic, linguistic and cultural differences, self-reported boredom is lowest when students spend time with friends, a leisure activity over which they have a high degree of decision-making power and is highest when students attend language and literature classes, mathematics classes, or during self-study at home.

Fig. 1 indicates that the vast majority of students in the eight countries analyzed reported not being bored at all when spending time with friends, with values ranging between 69% in Bulgaria and 87% in Spain. By contrast, boredom is highest during self-study: the share of students who reported not being bored at all while engaging in self-study ranged between 15% in Ireland and 43% in Georgia. These results provide support to the notion that boredom is a function of the situation in which 15-year-old students are and that respondents provided meaningful answers to the questionnaire since they have face validity.

5.2. The association between boredom and academic achievement

Fig. 2 reveals the association between boredom in academic settings – language and literature classes, mathematics classes, and self-study at home – and contemporaneous achievement in reading and in mathematics. Results can thus be used to answer RQ2. Fig. 2 indicates that students who report being bored in mathematics classes have lower achievement in mathematics in most countries with available data, although the association is small in size and it is not statistically significantly different from 0 in Bulgaria. The difference in academic achievement between students who report being bored in mathematics classes and achievement in mathematics is generally stronger than gender differences in mathematics achievement and corresponds to 11% of a SD in Hong Kong, 8% of a SD in Ireland, Mexico and Spain, 6% of a SD in Georgia, 5% of a SD in Serbia and 4% of a SD in Panama. By contrast, Fig. 2 does not reveal a

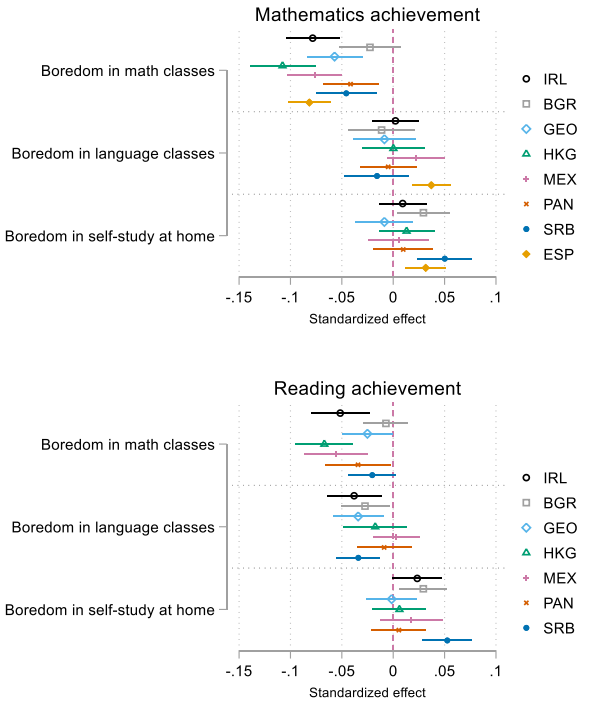

Fig. 2. Relation between students' academic achievement and self-reported boredom
Note: The Figure illustrates country-specific estimated standardized regression coefficients (and 95% confidence intervals) for key independent variables (boredom in mathematics classes, boredom in language and literature classes and boredom during self-study). Estimates were obtained by fitting two separate multilevel models. In the first model, reported in the top panel, the dependent variable was students' mathematics achievement. In the second model, reported in the bottom panel, the dependent variable was students' reading achievement. Independent variables included in all models are gender and ESCS. Detailed results from the regression models are available in Supplementary Online Annex Tables A5 and A6).

consistent association between achievement measures in mathematics and boredom in language and literature classes and boredom during self-study. In fact, students who report being bored during self-study have higher mathematics achievement in Bulgaria, Serbia and Spain. Students who report being bored in language and literature classes have higher mathematics achievement in Spain.

Fig. 2 does not reveal a consistent association between achievement in reading and academic boredom. For example, students who report being bored in language and literature classes have lower achievement in reading than those who do not report being bored in Ireland, Bulgaria, Georgia and Serbia. By contrast, students who report being bored in mathematics classes have lower achievement in reading than those who do not report being bored in Ireland, Georgia, Hong Kong, Mexico and Panama. Students who report being bored during self-study have higher achievement in reading than those who do not report being bored in Bulgaria and Serbia.

5.3. *Differences in self-reported boredom as a function of ICT use*

Next, we answer RQ3 by examining the association between students' self-reported boredom in academic settings – language and literature classes, mathematics classes, and self-study at home – and the extent to which they use ICT for leisure. We answer RQ4 by examining the association between students' self-reported boredom in language and literature classes, mathematics classes, and self-study at home and the extent to which they use ICT for learning both in class and at home. In Fig. 3 we report key coefficients of interest from LPM while full results, including estimates for all controls as well as robustness checks obtained by fitting ordered logistic regression models are reported in the Supplementary Online Annex.

Results reveal that the use of ICT for leisure is associated with higher levels of self-reported boredom among 15-year-old students in language and literature classes, mathematics classes, and self-study at home in the eight countries considered. Standardized

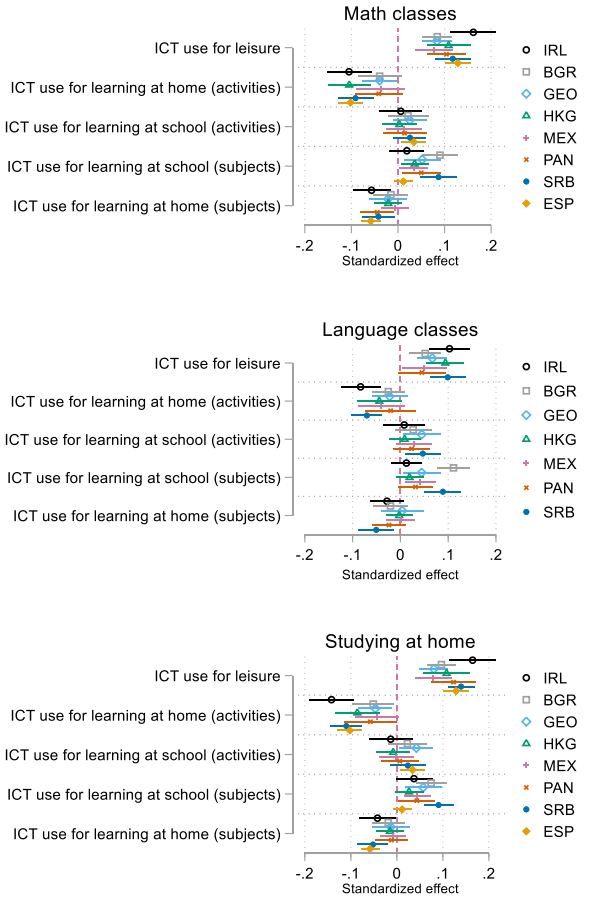

Fig. 3. The association between ICT use and academic boredom

Note: The Figure illustrates country-specific estimated standardized regression coefficients (and 95% confidence intervals) for key independent variables presented in the Figure. Estimates were obtained by fitting three separate multilevel models. In the first model, reported in the top panel, the dependent variable was students' reported boredom in math classes. In the second model, reported in the middle panel, the dependent variable was students' reported boredom in language and literature classes. In the third model, reported in the bottom panel, the dependent variable was students' reported boredom when studying at home. Independent variables included in all models are gender, ESCS, parents' emotional support, perceived teacher's enthusiasm and math achievement for models estimating boredom in math classes (or reading achievement for language and literature classes). Detailed results from the regression models are available in the Supplementary Online Annex Tables A7, A8 and A9).

coefficients, a measure of effect size, vary somewhat across countries and tend to be strongest in Ireland and Spain. On average, across the eight countries in our sample, a difference of one standard deviation in ICT use for leisure is associated with a difference of around 11% of a standard deviation (SD) in boredom in mathematics classes (ranging from $\beta = 0.162$ $p < .001$ in Ireland and $\beta = 0.129$ $p < .001$ in Spain, to $\beta = 0.076$ $p < .001$ in Mexico and $\beta = 0.084$ $p < .001$ in Bulgaria and Georgia), around 7% of a SD in boredom in language and literature classes (ranging from $\beta = 0.103$ $p < .001$ in Ireland and $\beta = 0.099$ $p < .001$ in Serbia, to $\beta = 0.045$ $p > .1$ in Panama and $\beta = 0.050$ $p < .1$ in Mexico), and around 12% of a SD in boredom in self-study (ranging from $\beta = 0.165$ $p < .001$ in Ireland and $\beta = 0.139$ $p < .001$ in Serbia, to $\beta = 0.079$ $p < .001$ in Mexico and $\beta = 0.080$ $p < .001$ in Georgia).

The use of ICT for learning at school does not appear to be strongly associated with students' self-reported boredom, although there are some differences in relations between the two indicators of ICT use for learning at school. Fig. 3 details that students who report a greater frequency of use of digital devices for a range of specific academic activities at school are just as likely as students who report a lower frequency of use to report being bored in language and literature classes, mathematics classes and self-study. By contrast, in many countries, students who report a greater frequency of use of digital devices to learn different academic subjects at school are more likey to report being bored in mathematics classes, language and literature classes and during self-study than students who report a lower frequency of use. For example, the association between the indicator of frequency of use of ICT at school to perform different learning activities and boredom in mathematics classes is statistically significant at least at the 5% level only in Spain ($\beta = 0.034$ $p < .05$). In the other countries it is quantitatively very small and not statistically significant at least at the 5% level. The association between the indicator of frequency of use of ICT at school to learn different academic subjects and boredom in mathematics classes is statistically significant at least at the 5% level in all countries except for Ireland and Spain and is largest in Bulgaria ($\beta = 0.090$ $p < .001$) and Serbia ($\beta = 0.087$ $p < .001$).

The use of ICT for learning at home is associated, other things being equal, with lower self-reported boredom, although there are some differences in relations between the two indicators of ICT use for learning at home and relations appear to be strongest when self-reported boredom during self-study is considered. A positive difference of one standard deviation in the indicator of the frequency of ICT use for learning at home to perform different learning activities corresponds to a negative difference of around 8% of a SD in boredom reported during self-study across the eight countries in our sample and is especially large in Ireland ($\beta = -0.142$ $p < .001$), Serbia ($\beta = -0.110$ $p < .001$) and Spain ($\beta = -0.102$ $p < .001$). By contrast, students who report greater frequency of use of digital devices to learn different academic subjects are statistically significantly less likely to report being bored during self-study only in Ireland ($\beta = -0.042$ $p < .05$), Serbia ($\beta = -0.052$ $p < .01$) and Spain ($\beta = -0.058$ $p < .001$).

5.4. *Teacher enthusiasm as a key moderator of the association between ICT use and academic boredom*

In order to answer RQ5 and RQ6 first we examine the association between teacher enthusiasm and students' self-reported boredom and then we examine the variation in the association between ICT use and boredom as a function of teachers' enthusiasm.

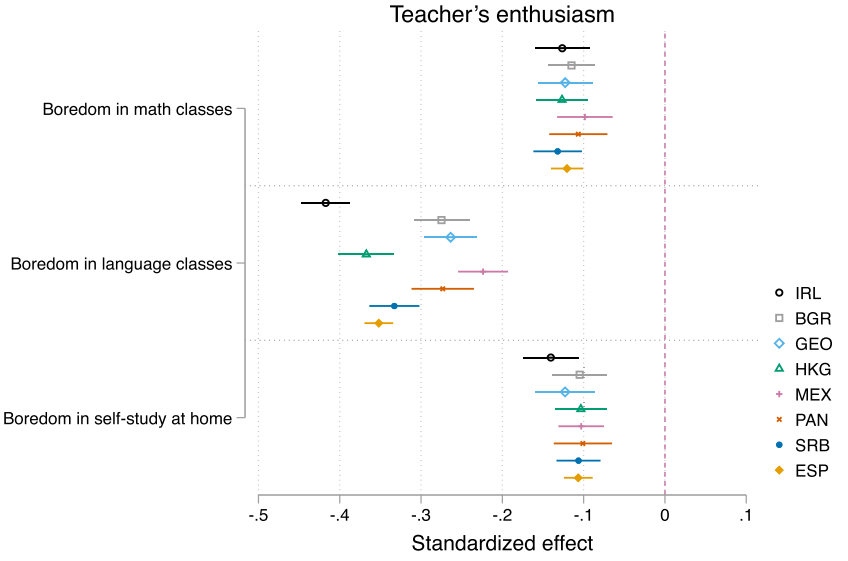

Fig. 4. The association between teacher enthusiasm and academic boredom (math, language and self-study at home)
Note: The Figure illustrates country-specific estimated standardized regression coefficients (and 95% confidence intervals) for students' perceptions of their teachers' enthusiasm, the key independent variables in three separate multilevel models. In the first model, reported in the top part of the figure, the dependent variable was students' reported boredom in math classes. In the second model, reported in the middle part of the figure, the dependent variable was students' reported boredom in language and literature classes. In the third model, reported in the bottom part of the figure, the dependent variable was students' reported boredom when studying at home. Detailed results from the regression models are available in the Supplementary Online Annex Tables A10, A11 and A12).

Fig. 4 indicates that when students perceive their language and literature teachers as enthusiastic, they tend to be considerably less likely to report being bored in self-study, as well as in mathematics and in language and literature classes. On average across the eight countries in our sample, a positive difference of one SD in teacher enthusiasm is associated with a negative difference of 12% of a SD in boredom in mathematics classes, of 31% in boredom in language and literature classes and 11% in boredom during self-study. Associations vary across countries, however. For example associations between teachers' enthusiasm and boredom in language and literature classes are highly statistically significant in all countries and are strongest in Ireland ($\beta = -0.417$ $p < .001$) and Hong Kong ($\beta = -0.367$ $p < .001$) and are weakest in Georgia ($\beta = -0.264$ $p < .001$) and Mexico ($\beta = -0.224$ $p < .001$).

Fig. 5 details the relative importance of different factors for boredom in language and literature classes using standardized regression coefficients. The choice of language and literature classes rather than mathematics or self-study was driven by the fact that detailed indicators of teacher practices used in language and literature classes are available in the PISA dataset and it is therefore possible to isolate the association between teacher enthusiasm and boredom net of other teacher practices or classroom factors. Results confirm that teacher enthusiasm is strongly associated with students' self-reported boredom in language and literature classes even after accounting for other teacher factors and classroom climate with are strongly correlated with teacher enthusiasm and boredom: teacher support, teacher's ability to stimulate engagement with reading and classroom disciplinary climate. For example, in Ireland, the country where teacher enthusiasm is most strongly associated with boredom in language and literature classes after taking into account for other teacher characteristics ($\beta = -0.266$ $p < .001$), standardized associations are considerably smaller between boredom and disciplinary climate ($\beta = -0.129$ $p < .001$), between boredom and teacher support ($\beta = -0.118$ $p < .001$), and between boredom and teacher stimulation of reading engagement ($\beta = -0.060$ $p < .001$). Mexico is the only country where the association between teacher enthusiasm and boredom in language and literature classes ($\beta = -0.112$ $p < .001$) is similar to those observed between boredom and other teacher factors ($\beta = -0.116$ $p < .001$ for disciplinary climate; $\beta = -0.118$ for teacher support $p < .001$; and $\beta = -0.087$ $p < .001$ for teacher stimulation of reading engagement).

Next, we examine in detail variations in the associations between different forms of ICT use and boredom in language and literature classes as a function of teachers' practices. Panels A and B in Fig. 6 suggest that, other things being equal, among students who perceive their teachers to be highly enthusiastic, the use of ICT for leisure is not associated with perceived boredom but among students who perceive their teacher not to be enthusiastic boredom is higher the higher the use of ICT for leisure students engage in. In general, students who do not perceive their teachers to be enthusiastic report considerably higher levels of boredom than those who perceive their teachers to be unenthusiastic. Moreover, among this group of students, ICT use for leisure is strongly and positively associated with perceived boredom. In fact. Fig. 6 illustrates a clear gradient with an increasingly more positive association between ICT use for leisure and self-reported boredom the less enthusiastic students perceive their teachers to be.

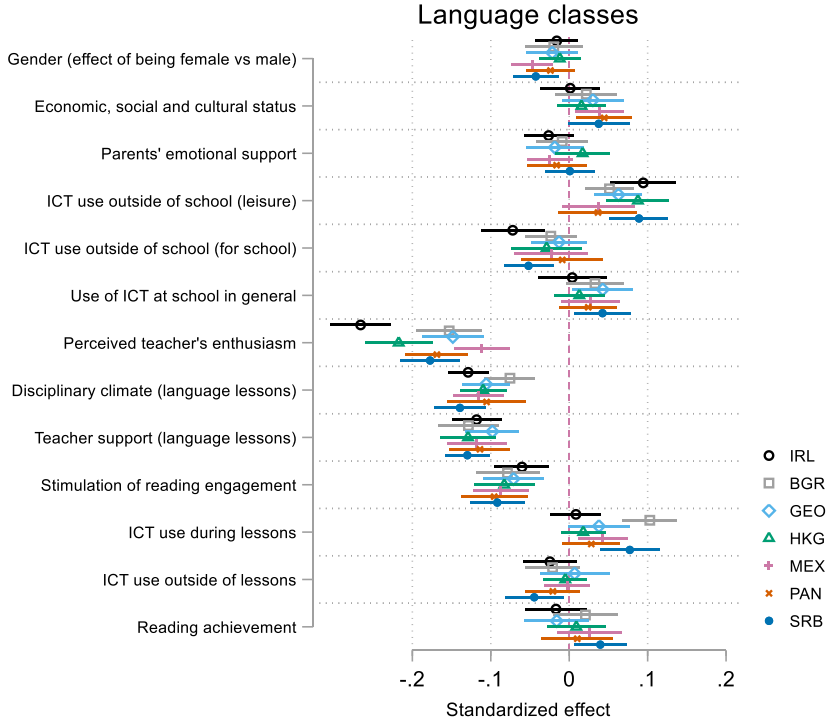

Fig. 5. Predictors of boredom in language of instruction classes

Note: The Figure illustrates country-specific estimated standardized regression coefficients (and 95% confidence intervals) for all independent variables used in the augmented multilevel model used to estimate boredom in language and literature classes. Detailed results from the regression models are available in Supplementary Online Annex Tables A13).

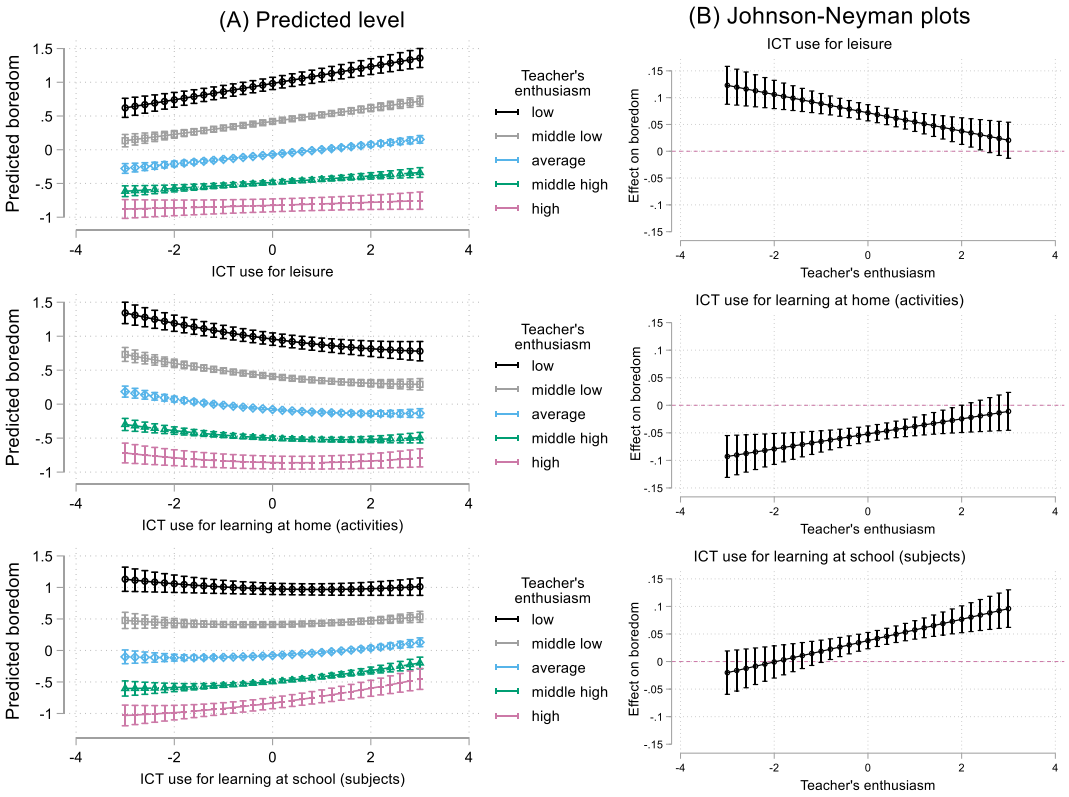

Fig. 6. Teacher enthusiasm as a moderator of the association between ICT use and boredom in language of instruction classes. Predicted level of boredom for different level of Teacher's enthusiasm and ICT use (panel A) and corresponding Johnson-Neyman plots (panel B)
Note: The Figure illustrates marginal effects (and 95% confidence intervals) of the interaction between teacher enthusiasm and the use of ICT at home (for school and for leisure) and at school, based on predictions for arbitrary cut-off points [-3, −1.5, 0, 1.5, 3] obtained from a multilevel regression estimating boredom in language and literature classes fitted on the pooled sample of countries. Country fixed effects were added alongside controls for gender, ESCS, reading achievement as well as the main effects for ICT use outside of school (leisure), ICT use outside of school (for school), ICT use during lessons. Detailed results from the regression models are available in Supplementary Online Annex Tables A14).

Panels A and B in Fig. 6 identify a very different interaction between teacher enthusiasm and ICT use for learning at home and at school. When teachers display low levels of enthusiasm, the use of ICT as a learning aid for learning at home is associated with lower levels of boredom. Among students who report that their teachers are enthusiastic, students report similarly low levels of boredom irrespective of how much they use of ICT as a learning aid. Interestingly, the use of ICT as a learning aid at school is not associated with boredom among students who perceive their teachers to be unenthusiastic whereas the use of ICT as a learning aid at school is associated with higher boredom among students who perceive their teachers to be very enthusiastic.

In order to examine between-country differences in the associations between different forms of ICT use and boredom in language and literature classes as a function of teachers' practices we estimated the same set of models represented in Fig. 6 independently for each country in our sample. Results of country-specific analyses are presented in the Supplementary Online Annex: Figure A1 illustrates Johnson-Neyman plots and Table A19 reports interaction coefficients between teacher enthusiasm and each indicator of ICT use. Results indicate that results are generally aligned with those obtained on the pooled sample, although most estimates are not statistically significant because we do not have enough power in the country-specific samples to be able to detect effects of the size of those identified in our analyses.

6. Discussion

Despite the lack of conclusive evidence on large negative effects of ICT use on key outcomes for adolescence such as academic achievement, psychological well-being and social connectedness, the increasing use of ICT among children has spurred growing anxieties among educators, politicians, and parents (Orben, 2020; Vuorre, Orben, & Przybylski, 2021). Many fear that children who use ICT regularly become used to the fast-paced interactive reality. In fact, the empirical literature suggests that ICT use can have both positive and negative effects, depending on the amount of use, the type of use, users' characteristics and the outcomes being evaluated (Vedechkina & Borgonovi, 2021; Chen, Lin, & Chen, 2021; Hu & Yu, 2021; Tautz, Sprenger, & Schwaninger, 2021), although specific forms of ICT use – such as social media use – may be especially harmful for specific outcomes – such as mental health (Haidt et al., ongoing). We set out to contribute to the evidence on the potential effects of ICT use among adolescents by considering the extent to

which ICT use is associated with a key motivational driver among adolescents: academic boredom. We used data from large, representative samples of 15-year-old students from eight countries with different cultural traditions, languages, and organization of schooling that took part in the 2018 edition of the PISA study.

6.1. Academic boredom is widespread across among 15-year-old students

Our results indicate that academic boredom is widespread among 15-year-old students. For example, as many as 85% of 15-year-old students in Ireland reported having been at least a little bored and almost a quarter (23%) reported being extremely bored when they last did their homework or engaged in self-study at home. By contrast, very few students reported being bored when they last spent time with friends: in Ireland as many as 84% of students indicated that they were not at all bored when with friends. Academic activities, which are often characterized by little sense of control and meaning for students, tend to be perceived as boring while activities over which students can exercise a higher sense of control are perceived as less boring. These results, together with the finding that teacher enthusiasm is negatively associated with the likelihood that an academic activity will be perceived as boring by students, are consistent with the predictions of the control value theory of achievement emotions.

6.2. The relationship between boredom and academic achievement differs across academic domains and contexts

In line with previous research, our results reveal a negative association between boredom in mathematics classes and contemporaneous mathematics achievement in most countries with available data (Ahmed et al., 2013). However, and contrary to previous findings we did not identify a corresponding widespread negative association between boredom in language and literature classes and contemporaneous reading achievement (Fritea & Fritea, 2013). Moreover, in some countries higher-achieving students are more likely to report being bored during self-study than lower-achieving students.

These results reflect the complex reciprocal relationship between boredom and academic achievement (Tze et al., 2016) and the fact that such interaction evolves over time (Camacho-Morles et al., 2021). In particular, because we are only able to identify contemporaneous associations between boredom and achievement, it is possible that our results reflect two separate mechanisms. On one hand, individuals are less likely to be bored when they engage in activities that they find meaningful and valuable. Individuals who have high levels of achievement in certain academic domains are more likely to find these domains meaningful (Tam et al., 2021) and to value them (Pekrun, 2006). On the other hand, high achievers may experience boredom during academic activities when teachers and educators fail to tailor the content of instruction to the level of proficiency of high achieving students, thus failing to sufficiently motivate them.

6.3. An extensive use of ICT is associated with higher levels of academic boredom

We find evidence that students who make extensive use of ICT for leisure, for example who use social media, play videogames or simply browse the internet for fun, are more likely, other things being equal, to report being bored when attending language and literature classes, mathematics classes, and, especially, when they are engaged in self-study at home. In order to keep engaged and motivated, students have to fight potential distractors, and this is more difficult to do during self-study when they cannot rely on external control and supervision, like the one they have in class. The fact that the use of ICT for leisure is associated with a higher likelihood that students will report being bored could be due to the fact that such use is more likely to be associated with attention and cognitive control disturbances, and thus to lower engagement and motivation. By contrast, the use of ICT for learning at home is associated with a lower likelihood that students will report being bored in language and literature classes, mathematics classes, and, especially, when they are engaged in self-study at home. This could be because ICT use for learning at home could promote students' engagement with learning. It could also indicate that students are less likely to report being bored when their teachers are prepared to consider a range of methods and approaches to learning and adapt these to the needs and expectations of students so as to promote a higher sense of control and meaning. Finally, we did not find evidence of an association between the use of ICT for learning at school and the likelihood that students will report being bored in class or during self-study at home.

6.4. The relation between ICT use and academic boredom differs depending on levels of teachers' enthusiasm

We find evidence that the association between ICT use and boredom is heterogeneous and depends on the level of enthusiasm students see in their teachers. More specifically, ICT use for leisure is associated with increased boredom in language and literature classes among students who do not perceive their teachers to be enthusiastic about teaching. Among students who perceive their teachers to be enthusiastic the amount of ICT used for learning for self-study did not matter to predict how bored they would report to be in language and literature classes. By contrast, among students who do not perceive their teachers to be enthusiastic, a higher use of ICT for learning for self-study was associated with lower boredom. Crucially, our results indicate that the use of ICT as a learning aid at school is not associated with boredom among students who perceive their teachers to be unenthusiastic but it is associated with higher boredom among students who perceive their teachers to be very enthusiastic. Other things being equal, when teachers are enthusiastic, the use of ICT in the classroom appears to be considerably less engaging than their teachers.

We examined between-country differences in the associations between different forms of ICT use and boredom in language and literature as a function of teachers' practices. Estimates of interaction effects for individual countries generally have the same sign and magnitude as those estimated on the pooled sample. Moreover Johnson-Neyman plots suggest that similar relations are observed for

individual countries. However, formal tests of statistical significance fail to reject the null hypothesis that many coefficients of interaction terms are similar to zero. This is because for individual countries we have relatively small samples and therefore lack power to detect effects sizes such as those estimated in our models. As Brambor, Clark, and Golder (2006) pointed out it is possible for the marginal effect of X on Y to be significant for substantively relevant values of the modifying variable Z even if the coefficient of the interaction term is insignificant. This means that it is not possible to decide whether a model should include an interaction term simply by looking at the significance of the coefficient of this interaction term. This is an important point which is often ignored in applied research, leading analysts to disregard potentially important conditional relationships between their variables (Brambor et al., 2006).

7. Conclusion, limitations and future research

The results presented in this work suggest that, given levels of use and the content of ICT programs and applications in 2018, levels of boredom expressed by students when engaging in language and literature classes, mathematics classes, and during self-study at home varied more in the eight countries in our study depending on teachers' enthusiasm than the amount of ICT used by adolescents. Moreover, the association between ICT use and the boredom 15-year-old reported experiencing during academic activities depended on how enthusiastic they perceived their teachers to be.

On one side, these results paint an optimistic picture: they do not lend support to the fears of those who believe ICTuse will inevitably reduce children's willingness and capacity to engage with school. They also reveal the continued primacy of teaching and teachers in the promotion of students' motivation to learn. At the same time, these results suggest that as technological innovations become more prevalent and varied, and as they come to be used both inside and outside classrooms, teachers become even more important to determine the outcomes of their students. Teachers who are enthusiastic about their work and who are able to mobilize a range of approaches to engage their students in order to provide them with a sense of control and meaning both during class and self-study at home, are able to harness the power of technology to promote positive achievement emotions.

Despite the fact that our study is the largest to date, involving 76,818 students from eight countries, it also suffers from a number of limitations that should inform how our results are interpreted and guide directions for future research. First, our study relies on information reported by students on how they felt the last time they attended mathematics classes, language and literature classes, and when they last did their homework or studied for school. By contrast, students were asked to report about their level of ICT use in general and therefore there is lack of consistency across the two sets of measures. Furthermore, the last class might not adequately represent a typical class. This would not be a problem at the population level if one were to assume that on average the last class resembled the average class experienced by students. However, since the PISA testing window is narrow, it is possible that levels of boredom reported by students reflect what part of the curriculum is being covered at the time of the test administration and/or how appealing being outside of class is (for example the same class could be perceived as more boring during a sunny and warm day and less boring on a rainy and cold day by some students). The reason why questionnaire developers used different formats for the two sets of questions may be, among others, that levels of ICT use are probably less affected by recollection bias than self-perceived boredom and therefore general statements about ICT use are more likely to be accurate than general statements about boredom. Moreover, theory suggests that general use of ICT might shape the transitory experience of boredom.

Second, the review of the literature makes clear that boredom is a complex, multidimensional concept that characterizes a well-defined state that is related to, but is conceptually distinct from, other psychological concepts that shape students' engagement and motivation. It is possible that students in different countries, and different groups of students, might report being bored when they experience different states or might not all report being bored when, in fact they are experiencing a similar state of wanting to but being unable to engage in a satisfying activity. Further work could explore further how best to include valid and reliable indicators of academic boredom in a cross-country setting.

Third, our study is cross-sectional and correlational in nature. Therefore, our results remain descriptive and cannot be interpreted causally. For example, reverse causality may mean that students who are more prone to be bored are more likely to use ICT during their leisure time (Elhai, Vasquez, Lustgarten, Levine, & Hall, 2018; Leung, 2015, 2020). Teachers are also less likely to be enthusiastic in classrooms with disengaged and uninterested students than in classrooms with motivated and engaged students.

Fourth, although we were able to control for a wealth of teacher and classroom factors, we were unable to control for detailed characteristics associated with ICT use, which may mean that our results could reflect omitted variables. Our measures of ICT use also lack precision and do not reveal potential differences in the content and the quality of use.

Fifth, because both boredom and teacher enthusiasm are reported by students, it is possible that the strong association that we identify could be due to the fact that some students may be less likely to experience boredom and be more likely, given the same behavior of teachers, to perceive them as more enthusiastic.

Sixth, because the PISA sampling strategy does not allow to identify students who attend the same class and who share the same teacher, we could only formally consider interdependence at the school, rather than classroom level. Furthermore, although we were able to report findings from large representative samples in several countries and discuss similarities and differences between different countries in key results, our sample of countries is restricted. Therefore, associations depicted should be considered to reflect a specific historical period and situations in eight countries and may not generalize to other contexts. This also prevents us from analyzing if differences in relations across countries are systematically related to cultural traditions or institutional arrangements the same way in which PISA, for example, has been used to consider the role of inequality, the level of standardization of the educational system or early tracking in shaping cross-country differences in the size of the gender and socio-economic gaps in achievement (Guiso, Monte, Sapienza, & Zingales, 2008; Van de Werfhorst & Mijs, 2010; van Hek et al., 2019, Buchmann, & Kraaykamp, 2019).

Future research could remedy these limitations by exploring the associations between different forms of ICT use, boredom and

teacher enthusiasm using more detailed instruments of ICT use and boredom and indicators of teacher enthusiasm beyond the self-reports of students under analysis. Moreover, although it would be difficult to identify causal evidence through experiments, longitudinal evidence and/or quasi experimental strategies could help identify the causality of underlying associations and the specific circumstances that drive affective reactions to ICT use and classroom climate. Although the strength of research conducted using large-scale international assessments is that it is highly generalizable since it typically involves large representative samples from multiple countries and standardized administration conditions, researchers have exploited matching techniques, quasi experimental strategies such as difference in difference estimation and instrumental variable approaches to identify causal effects using large-scale assessment data (Rutkowski, 2016). Future research could attempt to exploit differences in institutional rules, in the geographical and temporal spread of technologies, personal characteristics or testing conditions to identify the effect of ICT use and teacher characteristics (Borgonovi & Biecek, 2016, Borgonovi & Han, 2020; Beneito & Vicente-Chirivella, 2022).

Given existing large-scale international assessments and surveys, assessing relations in a broader set of countries is not possible because data are not available. Should our study and other similar work convince data developers about the importance of mapping academic boredom alongside other motivational constructs in the context of International Large Scale Assessment Initiatives like PISA, the Programme for International Reading Literacy Study (PIRLS) or the Trends in International Mathematics and Science Study (TIMSS), future analyses could broaden country coverage and identify how generalizable our findings are to a range of contexts differing in ICT use, culture and level of economic development. An expanded country coverage would also allow to study if differences in the strength of relations across countries might be related to differences in culture, institutional features of educational systems or the organization of schooling. Moreover, because the PIRLS and TIMSS studies rely on classroom sampling, should boredom be included in these studies, analyses could reveal in greater detail the role of classrooms and teachers' behaviors in shaping students' academic boredom. Understanding if and how education systems in general, and teachers in particular, can promote students' achievement-related emotions will become increasingly critical at a time of rapid technological development. Whereas it may be impossible to closely monitor and regulate children's use of ICT, our study suggests that the achievement-related emotions felt by users of ICT may depend on the attitudes, dispositions and preparedness of their teachers.

Authors' contributions

FB conceived the study, designed the analytical method, drafted the manuscript and provided overall direction and planning. MP conceived the study, reviewed the literature, drafted the manuscript. AP conceived the study and performed the analyses.

Data availability

We stated in the paper that all data are public and highlighted where data can be downloaded

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2023.104807.

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