The use of robotics embedded in playful learning scenarios in secondary schools: Teachers' and students' perspectives

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Abstract
Educational robotics integrated with playful and peer-learning approaches can help transform teaching and learning; yet, it is under-utilised in non-ICT related subjects in the secondary sector. This study sought to explore: a) the process underpinning playful learning scenarios integrating robotics; b) the learning experience both from the students' and the teachers' perspective; c) the impact of robotics integration on pedagogical practices. We investigated two learning scenarios through participant observation and semi-structured interviews with a purposive sample of students and educators. Subsequently, we transcribed the interviews and carried out inductive thematic analysis on all the data. Analysis from both sets of responses indicated that the teacher's mindset plays a key role in the use of robotics to attain the learning outcomes utilising playful scenarios. Consequently, this has a ripple effect on the students' learning and engagement.

Keywords
Playful learning, robotics, pedagogical approaches, mindset

Introduction
Digital technologies have developed and advanced at a rapid pace; however, schools seem to respond to this change relatively slowly (Facer, 2012). Advancement of robotics has opened new hands-on opportunities to learning environments. Although robotics has been integrated in a cross-curricular manner in primary education (Sullivan & Bers, 2015; Cutajar, 2019; Yuan et al., 2019), its use in secondary education is often restricted to supporting the

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teaching of robot programming and construction (Mitnik, Nussbaum, & Soto, 2008).

This paper explores the process underpinning playful learning scenarios integrating robotics in secondary education, the learning experience from students' and teachers' perspectives and the impact of robotics integration on pedagogical practices that go beyond learning robot construction.

Background

Play, games, robots and learning

Early scholars studied play and its affiliation with learning and cognitive development (Bruner, 1983; Dewey, 1910; Piaget, 1962; Vygotsky, 1978). Piaget (1962) considered play as assimilation: during play children do not form new cognitive structures but use existing schema to comprehend new experiences. However, Vygotsky (1978) argued that play fosters cognitive development by creating a 'Zone of Proximal Development' (ZPD), which acts as the knowledgeable other extending children's learning abilities.

When students play games within their ZPD, a sense of motivation is fostered as they are challenged within their skill level (Malone, 1980). This, together with the advancements in digital technology, including game development, has introduced the game itself to education (de Freitas, 2006; Squire, 2003), defined as game-based learning (Tang et al., 2009). Various studies explored digital games' enhancement of learner engagement, indicating that game-based learning promotes a positive approach towards learning. It aids retention, self-constructed learning and developing of cognitive and social transferable skills such as critical thinking and teamwork (Boyle et al., 2016; Cojocariu & Boghian, 2014; Hung et al., 2014; Terri, 2014; Gee, 2007). Other researchers extracted learning principles, which gamers master through video play without using the game itself, to transform the educational learning experience (Gee, 2005, 2007). The impact of including game design elements, such as challenge, feedback, progression and reward, promote active learning in classrooms and help in achieving learning outcomes (Barata et al., 2013; Mohamad et al., 2017).

A recent shift from gamification to a broader range of playful approaches is 'playful learning' (Whitton, 2018), that occurs inside 'the magic circle' (Huizinga, 1955), a space which can explain how people construct relationships and realities during play (Salen & Zimmerman, 2004). This 'magical circle of playful learning', referred to in this study as 'playful learning' has three characteristics: intrinsically motivated learning; learning accessed through a spirit of play and experimentation; and embracing failure during play that acts as an essential part of the learning process (Whitton, 2018). Papert's (1980) early work dealt with the idea of using robotics to teach subjects such as planar geometry, a non-ICT related subject. Robots in the hands of students are novel playful tools that can be used in non-ICT related subjects, both to trigger students' interest and to enhance student learning in several subjects (Whittier & Robinson, 2007; Williams et al., 2007; Owens et al., 2008).

Student-centred pedagogical approaches

The influence of constructivist learning theory (Hannafin et al., 1997) led to a shift to student-centred approaches to stimulate knowledge construction (Baetan et al., 2016; Ertmer et al., 2012), where emphasis is on students' active participation in learning (Cannon and Newble, 2000). Technology-aided student-centred learning can help students develop 21st century skills, such as thinking, communication, collaboration, and problem-solving (McCain, 2005; Ertmer et al., 2012). Robotics integrated with playful learning in collaborative groupings can provide safe spaces within the student's ZPD (Vygotsky, 1978), where failing does not lead to serious consequences and the student is motivated to re-try as the challenge is not too difficult (Malone & Lepper, 1987; Whitton, 2007).

The student's changing role in student-centred learning environments necessitates the teacher's role to move from a didactic style, where teachers present information and manage the classroom, to one which guides discovery and models active learning, stimulating students to question and thus becoming active collaborators (Ertmer et al., 2001; Ertmer et al., 2012; Pratt 2008). Other learner-centred pedagogies built on social constructivist theories, including inquiry-based learning, problem-based learning, project-based learning, experiential learning and gamified learning, give students an active role, develop their curricular knowledge and understanding and help them attain 21st century skills.

Research context and purpose

Locally, robotics was introduced in an optional secondary subject, Computer Studies, in 2010 (Directorate for Learning and Assessment Programs, 2020). Subsequently, all secondary students were exposed to the C3 'Computing Competency Certificate' to help them develop core digital fundamentals (Catania, 2019), leading schools to invest in new robots. These robots can trigger students' interest and enhance student learning; however, presently they are not well integrated across the secondary school curriculum and there are virtually no local studies on this. Therefore, this study sought to investigate robotics use in playful learning scenarios in non-ICT related secondary subjects in Malta, by addressing these questions:

i) What is the process underpinning teachers integrating students' use of robotics in playful learning scenarios to reach their learning outcomes?

ii) What is the learning experience from both teachers' and students' perspective?

iii) What is the impact of robotics integration on pedagogical practices?

Two secondary church school teachers showed interest in developing their teaching practices by using robotics in their classroom and created a pedagogical framework aligned with the curriculum with support from the researchers on the cross-curricular use of the robots. *Ozobots* are robots small enough to move on students' desks, programmed either through drawn colour codes or through block coding. The teachers chose three aspects of playful learning, namely tools, techniques and tactics (Whitton, 2018), and integrated them into their planning. Through colour coding integrated with teacher-developed supporting sheets, the robots acted as 'playful tools', adding context to the challenge as they travelled along a track to create meaningful playful learning environments and experiences (Whitton, 2018).

In Lesson 1, students applied mathematical concepts to problems, where the numerical answer was linked to a particular colour code. In Lesson 2, students applied team building concepts learnt in the Prince's Trust Achieve Programme, a subject intended to instil personal development and employability skills in practice (Ministry for Education and Employment [MEDE], 2016). In pairs, students had to solve problems to guide the robot to take the correct turnings through intersections, avoiding teamwork disadvantages to reach the end of the track.

Research design

A qualitative methodology was adopted to enable an in-depth exploration of the implementation and planning process of this pedagogical approach and elicit the dynamics both from teachers' and students' perspectives.

Data were generated through:

i) Participant observation in four 50-minute lessons with 60 students aged 11 to 14 years from mixed-ability classes;

ii) Semi-structured audio-recorded interviews with two teachers and seven students selected by maximum variability sampling to cater for different ages and abilities, which were transcribed verbatim.

Permissions to conduct the study were granted by the Secretariat for Catholic Education and the Head of School. Teachers, students and their parents signed informed consent forms after being given information about the nature of the study and their participation. Participants were reassured that they could withdraw from the study without any repercussions and pseudonymity was maintained. Table 1 summarises the participants' pseudonyms and the lesson they participated in.

Interview transcripts and observation field notes were analysed by inductive thematic analysis, guided by Braun and Clarke's (2006) approach. Analysis was not linked to predefined theoretical models and enabled a rich description of the whole data reflecting a range of experiences and attitudes (Bryman & Burgess, 1994; Braun & Clarke, 2006). Prior to thematic analysis, to compare the wealth of qualitative raw data collected from the interviews, word clouds were generated by wordart.com (selected for its formatting options) from the transcripts (Mathews et al., 2015). This served as quality control to ensure that students' and teachers' perceptions were sufficiently represented and that no key themes were missed (Ardito et al., 2014; McNaught & Lam, 2010). Teachers' and students' responses were dealt with separately. Common words were eliminated and inflected words were reduced to their word stem by the software (McNaught, 2010). To ensure consistency across word clouds for comparability purposes, the same font and style were used, whereby the font size represented word frequency (Vrain & Lovett, 2020).

Subsequently, after multiple readings of the interview transcripts to ensure familiarisation with the data, key issues were identified through open coding. Keywords were generated from the data, rather than from predefined categories, thus enhancing authenticity and maintaining an inductive approach (Patton, 2002; Braun & Clarke, 2006; Creswell, 2014). A thematic map incorporating themes and sub-themes was drawn up. Reflexivity and trustworthiness were enhanced by maintaining a transparent process, working collaboratively and iteratively cross-checking overlapping themes, ensuring that the coding and analysis truly reflected the data. Thus, generated themes and sub-themes were refined and condensed into more meaningful analytical categories.

Table 1: Participants' Pseudonyms and Lessons

Participant	Lesson	Pseudonyms
Teacher 1	Maths Lesson	T1
Student 1		S1
Student 2		S2
Student 3		S3
Student 4		S4
Teacher 2	Prince's Trust Lesson	T2
Student 5		S5
Student 6		S6
Student 7		S7
Participant Observer	Maths and Prince's Trust Lessons	PO

Results and analysis

The fifteen most frequent terms that emerged from the word clouds (Figures 1 and 2) indicated the focus of the students' and teachers' responses (Atenstaedt, 2017).

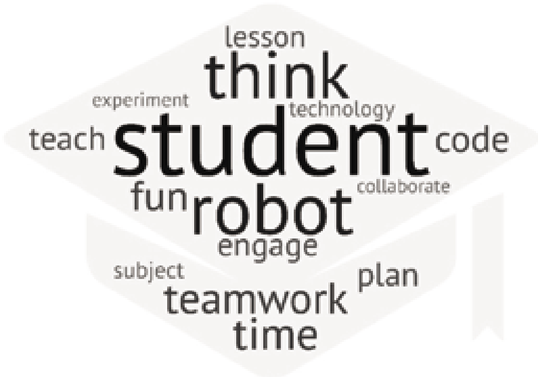

Figure 1: Teachers' Word Cloud

Figure 2: Students' Word Cloud

Following cloud analysis and thematic coding, three main themes emerged from both the teachers' and students' perspectives, presented in the following subsections, to give a deeper and more comprehensive insight into the process underpinning robotics integrated in playful learning scenarios.

Mindset

Teacher's Perspective

Both teachers were "open to try out novel things, to help the students learn better and motivate them [and] … were ready to work collaboratively with the trainer" (PO). T1 expressed that she needed to "think more outside the box", describing how she overcame her fear of classroom technology use and her shift to an open mindset: "I was a little sceptical whether I would manage to use them [the robots] … [but] I moved out of my comfort zone and it felt good."

Similarly, T2 mentioned how "you open your horizons, and you try to avoid staying within your usual methods of teaching … [as it] can offer a very enriching learning experience to our students." This agrees with Phillips and Condy's (2020) reflections that "the professional teacher needs to realise the potential of new technologies and the advantages of including such new ways of exploring the landscape of learning in the fourth industrial age" (p. 214).

When an educator resorts to an authoritarian teaching style, students become passive learners in adopting little or no dialogue at all (Phillips & Condy, 2020). Contrastingly, both teachers embraced a growth mindset and designed positive learning environments:

> … [the students] were motivated … more eager for the lesson … with a more positive attitude towards the subject … when something interests them, they are more ready to listen to you as a teacher … you also build a better rapport … you get to know them better … we try our best to help them, we are not making them learn things by heart (T1)

> "after the activity they wanted more … to explore further" (T2).

Students' Perspective

The positive shift in the teachers' mindset was reflected in the students' responses:

> "most definitely, [the lesson] was different, it was exciting" (S1)
>
> "[we] hope [we] get the opportunity to do this again" (S2).

Some expressed that "it felt great" (S5), "[I] felt very happy … excited" (S7), and "there was energy" (S1).

Students exhibit a positive attitude towards learning when education encompasses playful elements (Terri, 2014), as "a growth mindset response to a challenging task is eagerness to learn" (Campbell et al., 2019, p. 36). Additionally, growth mindset beliefs result in changes in students' behaviour, resulting in deeper learning and persistence (Campbell et al., 2019), as reflected in S1's response: "you're having fun learning the topic, you want to learn the topic, you're there, you're also learning other things."

Fixed and growth mindsets that revolve around beliefs and attitudes held by individuals about intellect and learning can explain how humans make meaning of the world around them (Dweck, 2006). Learners with a fixed mindset believe that their capabilities are fixed and cannot flourish further, while those with a growth mindset thrive, as they believe that with practice, their capabilities can flourish over time. In this study, teachers adopted an open and positive mindset which impacted their students' mindset, resulting in a more positive approach towards the lesson and better teacher–student relationships. This ripple effect aligns with Dweck's (2006) idea that mindsets do affect human behaviour.

Learning curve

Teacher's perspective

Through this experience, T1 "learnt something new [herself]." She "knew little about robotics [but she] always tried to learn," resulting in a personal positive learning drive that she subsequently instilled in her students:

> "you prepare them for independent learning [and] … they would be capable to learn from their own experience … they were learning, and I was learning from them." (T1)

Teacher-student partnerships were enabled by digital access as both students and teacher share and grow in these more meaningful teaching and learning experiences (Rosenstock, 2014; Camilleri, 2017). The teachers' mindset was aligned with Hercz et al. (2020)'s views that in today's world, educational professionals must "educate children to be prepared for life-long learning and sustainability-wise thinking" (p. 46), so apart from learning the subject's curriculum, the students learnt other skills. The students "did not memorise it but they learnt the skill … [also] learning from their own mistakes" (T1]. There was no fear in "getting something wrong … no frustrated faces", but a full "drive to try again and check what [was] wrong to get it right" (PO). Furthermore, mathematics "did not remain something fearful" and unmanageable, "it became more tangible, approachable as a subject [and students could] incorporate something of daily life during a subject that requires much more critical thinking and problem-solving skills" (T1). The students "could be seen tinkering and playing with these new robots until they got them working" (PO). This aligns with Dweck's (2010) belief that "meaningful work can also teach students to love challenges, to enjoy effort, to be resilient, and to value their own improvement" (p. 16).

Furthermore, teachers mentioned that "collaboration is a skill … they [students] learnt (…) from when they are young" since "in the world of work you need to know how to collaborate with others … to work as a team" (T1). Thus, educators favoured "peer-to-peer learning" (T1) so that students got to communicate and collaborate:

> The ozobot itself aided in communication between the students since they were working as a team, they had no choice and they had to agree between themselves, to see how they are going to make all things work … so communication was basically taking place all the time. (T2)

Students' perspective

Students expressed that:

> "if we fail, we have to see what we did wrong. It was fun seeing what we did wrong … [so] we could do it right" (S6)

> "if I did a mistake in the sum, and the robot took a wrong path, most definitely I would rework the sum again" (S1).

Both Dweck (2006) and Whitton (2018) look at failure as a constructive learning experience where failure is part of a positive learning growth whereby "the magic circle of playful learning provides a space in which participants have freedom to fail" (Whitton, 2018, p. 3). Failing in a mathematical task can cause negative thoughts and ruminations, increasing mathematics anxiety, leading to further failure to solve subsequent mathematics problems as people with high mathematics anxiety must deal with negative thoughts while simultaneously attempting to solve the mathematical problem (Ashcraft & Kirk, 2001; Ramirez et al., 2018). Data reflects that the safe playful learning zones created in mathematics, "a subject that a lot see boring and one in where there are many misconceptions" (T1), could have reduced students' anxiety levels as they persevered and took a deeper approach to learning as it made them "think harder" (S6), and "[they] don't want to make a fool of [themselves]" (S1). Thus, students find "innovative ways to solve problems, and if their method does not work, they will look for a new one" (Jaffe, 2020, p. 255). Students confirmed that they engaged in peer-to-peer communication and collaborated to reach a common goal.

> "[The lesson] helped me understand teamwork more … teamwork makes it faster and easier because we can communicate" (S5)

> "we were working together during the lesson … as a team … skills that we normally don't really use in normal Maths lessons" (S3).

Both stakeholders underwent a learning curve, embracing intellectual and cognitive skills as they underwent the experience of learning by doing things. This aspect highly relates to Bers's (2008, 2010, 2012) work and ideas whereas engagement with technology assists students in acquiring new skills. Similarly, the Positive Technological Framework identifies that when in casual scenarios students use technology, this results in positive behaviours that act as a learning gauge (Bers, 2012).

Teaching and learning approaches

Teacher's perspective

"In these types of sessions, it is the children that are at the centre, and the teacher is the one who facilitates the things, the one that helps them arrive to the learning outcome" (T1). Both educators expressed that building on the students' learning styles and interests is crucial to leaners' involvement in a student-centred approach (Lewis, 1992; Ebeiling, 2001; Riding, 2002). Actually, teachers stated that they "knew it was going to be a success, knowing the students … it was going to … draw their attention to know more about it" (T2); and "if you introduce robotics in lessons … as now technology is part and parcel of the life of today's generation, … I reached a wide variety of learning styles, those that learn by using tangible objects and even the bright ones" (T1).

Such pedagogies require a shift in the teacher's role, where the intervention of an adult is more of a "facilitator" (T1), as opposed to interfering, so the learning experience can be enjoyable, nourishing creativity, cognitive processing, and acquisition of new knowledge (Wood, 2013; Engel, 2015). Both teachers reported that including playful elements in their sessions was "like the oil in a machine, you gave [the students] an incentive, a motive to think further … perseverance," thus creating "more engagement … increasing student's motivation" (T1), as the sessions were fun, flowing and the approach was "visual and tactile" (T1).

Notwithstanding all this, teachers voiced their concerns that: a) more training is required since they "had to personally go through the process of how [the robots] work … [and] looked for documentation within the school building" (T2); b) mentoring is needed "because it is one thing to see and it is another thing when you are actually going to deliver the lesson with something that you are not too familiar with" (T2); and c) "lesson time is limited" (T1), resulting in the need that "these type of activities should be more on the education agenda, because … they are not being integrated enough in the curriculum" (T2).

Students' perspective

Nowadays, students prefer not to settle with knowledge acquisition through a delivery approach but build their own, based on their active experiences (Elliott et al., 2000). This was expressed by S6: "when you are in Grade 1 you had more fun because … more hands-on experience". They engage with learning as a way of making meaning (Zittoun & Brinkmann, 2012). Despite their different abilities, all students affirmed that the lesson met their learning styles: "a good example of trying different things" (S2); "hands on, something exciting … I think that I definitely prefer this method" (S1); "a fun learning experience … finally [we are] making the decisions here" (S6). Furthermore, students mentioned that the lesson was "kind of a competition" (S3) and the "steps that [they] learnt in Form 1 [were applied] in practice" (S4). The students turned the activity into a "friendly competition" (S1), an element of playfulness that can be used to motivate individuals to learn (Julian & Perry, 1967, Malone & Lepper, 1987). The students reflected that as they progress to secondary schooling, such opportunities are replaced with more authoritative teacher-talk approaches, "where you cannot say anything, all you do is just listen to a lesson, sit in a place [and] get bored" (S1). Students' responses show that instead of using textbooks as tools to aid teaching and focus upon educating the child holistically, educators are using books as a means to an end and feeding the child what is in the textbook, whether it is relevant to the child or not (Ollin, 2008). The learners' voice was clear that this is not what they want.

> "[the lesson] doesn't need to be the normal way, time is changing, you need to change the way. It has been rather the same method for quite some time now" (S1)

> "the ways of teaching through book … is out of date … [here] we did more instead of learning through the textbook, we learnt more through activities" (S6).

Integrating technology aids with this type of pedagogy into an everyday lesson increases opportunities for learners to explore interpersonal 21st century skills such as communication, problem-solving and collaboration, while being in control of their own learning (McCain, 2005; Ertmer et al., 2012). Additionally, playfulness enhances engagement, motivation and focus, encourages children to observe, think and problem-solve, while enriching them with the necessary skills to face problems optimistically, knowing that they can be solved (Cohen, 1993; Wood, 2013).

> "it's cool … it was enjoyable [and] more energy put into the lesson" (S1)

> "I was excited because we were doing some small programming" (S6)

> "it is more fun to solve the problems … I participated more than I usually do" (S2)

"Educational theory always questions ... who is taught? ... what should be taught ... [and] how? ... highlighting that the effective teaching-learning process is a core issue of the present-day pedagogy" (Hercz et al., 2020, p. 46). Data showed that pedagogies should revolve around the learner, and employ playful learning environments that increase engagement and development of 21st century skills and the importance of teachers' and students' voice in the educational system.

Discussion

This study tapped into the under-researched area of how educational robotics can be integrated in non-ICT related subjects and if their use stirs a shift in teaching-learning practices in secondary education.

Findings distinctly connect the pedagogical justifications of playful approaches being applied to learning in secondary education as they build on the three fundamental principles of "the magic circle" (Huizinga, 1955; Whitton, 2018), thus providing answers to our three research questions. In our study, both learning environments provided a safe space where playful collaborative learning allowed the learners freedom to fail; indeed, they embraced failure as a necessity (Whitton, 2018), and as part of the iterative process that motivated them to revisit their work and build resilience (Holdsworth et al., 2018). The challenge was not too difficult (Malone & Lepper, 1987; Whitton, 2007) but within the student's ZPD (Vygotsky, 1978). The ZPD, enhanced with collaborative playful opportunities within the "magic circle" (Huizinga, 1955; Salen & Zimmerman, 2004), allowed learners to construct relationships and knowledge during play as the "more capable peer", the robot's movements, and mentoring from the teacher provided regular and timely feedback that helped the learners extend their learning capabilities (Vygotsky, 1978). This feedback, together with small successes at an appropriate level, can increase the player's self-efficacy through failure (Wood & Bandura, 1989). As students immersed themselves in their ZPD, where a balance between their skills and challenge level was achieved, they entered "a state of flow" (Csikszentmihalyi, 1990, p. 4), which in turn enhanced intrinsic motivation, keeping them engaged throughout the activity as they "turn[ed] failure into curiosity" (Juul, 2005, p. 49), giving rise to feelings of satisfaction on task completion (Whitton, 2018). This helped students take more ownership of their learning as this nurtured the ability to focus on process and challenges of learning rather than the measurable outcomes, all features of a growth mindset (Dweck, 2010). This might create conflicts within formal education assessment systems where attention is more on measurable outcomes (Whitton, 2018).

Results suggest that learners have more positive attitudes and expectations based around fun. However, integrating fun into learning has its risks, associated with "sugar coating" (Dewey, 1902, p. 482). The robots acted as an external incentive to hook the students; however, careful teacher planning incorporating the right pedagogical and playful learning approaches (tools, techniques, tactics) (Whitton, 2018) enabled students to become intrinsically motivated to progress, review their work and learn in a fun, personal, explorative and collaborative atmosphere rather than through external rewards (Whitton, 2018). Consequently, there needs to be a balance between affective considerations and cognitive engagement during the learning activities.

This shed light on our first two research questions which sought to explore the process underpinning playful learning scenarios integrating robotics and the teachers' and students' learning experience. The pedagogy implemented required a transformation in teachers' beliefs, pedagogical thinking and mindsets which subsequently resulted in a positive learning curve for both the teachers and students (Ertmer et al., 2012). Teachers reflected that merging robotics with playful scenarios was worth the planning and learning time invested in the whole process. They put the students at the centre of the process, by actively engaging the different ability students who took pride and ownership in their learning whilst having fun. Various studies have studied the limiting factors to why teachers do not consider embedding technology in their lesson (Ng & Gunstone, 2003; Demiraslan & Usluel, 2008) or make use of it in student-centred ways (Uluyol & Sahin, 2016), with one of them being limited time for planning due to extensive curriculum demands. Teachers with a growth mindset may give less importance to such limiting factors when it comes to designing student-centred learning environments.

Teachers and designers of learning environments draw on a combination of pedagogical approaches, experimenting daily and building further on their professional knowledge and skills as they adapt to constantly changing situations (Paniagua & Istance, 2018). Our study affirmed the previously identified importance of supporting and mentoring educators (Mataric, Koenig, & Feil-Seifer, 2007), as most teachers are not equipped to integrate robotics into their teaching.

Regarding the third research question about the impact of robotics integration on pedagogical practices, the findings suggest that the pedagogical approach adopted by both teachers in integrating robotics allowed for the three elements of the magic circle to be in place: intrinsically motivated learning, that is accessed with a spirit of play, and where failure acts as a constructive learning condition (Whitton, 2018). Consequently, the pedagogical approach created a healthy learning environment where students themselves created friendly competition. However, when designing such environments, teachers need to limit excessively competitive activities as this can result in increasing anxiety and impede task performance (Kohn, 1992). Furthermore, in both learning scenarios, robotics use was not the ultimate aim, but a means to an end. Therefore, "technology [was] used as a cognitive tool … to achieve meaningful learning outcomes" (Jonassen & Reeves, 1996, as cited in, Yuan et al., 2019, p. 710). Hence, there was learning *with* (rather than *from*) technology and apart from achieving the subject's learning outcome, problem-solving and other 21st century skills, other skills were learnt in the process (Ardito et al., 2014).

Campbell et al. (2019) note that, educators "have the power to influence growth or fixed mindsets through [their] instructional design, whether or not [they] intend to do so" (p. 45). Both educators in our study adopted a growth mindset, shifting towards a student-centred approach in their teaching practices, and this resulted in a similar shift in the students' mindset. Students want to be included in the learning process with teaching that is relevant to them, including playful learning opportunities supporting hands-on approaches that frequently generate a joy of learning (Csikszentmihalyi, 1990; Resnick, 2006). Students also felt that the current teaching methods employed are outdated and need to change. Teachers are realising that it is hard to motivate 21st century students, who are deeply embedded in technology use (Prensky, 2010). This aspect was vividly brought up by the students themselves and show that a) students are not passive learners anymore but want to be engaged with what they are being taught; b) they want their time at school to be a positive part of their learning curve with learning that is relevant to them; and c) the student's voice is not being adequately heard.

Conclusion

This small-scale study was carried out with male students, so by no means can it be representative and generalised. Further similar studies could use classroom observations supplemented by interviews to obtain more in-depth data. Furthermore, such studies can be carried out with mixed-gender classes in diverse subjects where students are co-designers of the playful elements to give students more choice and voice in the process.

Cultivating a growth mindset culture, is crucial to lead teachers to develop student-centred, technological, playful teaching and learning environments that reflect the 21st century world. Such learning environments allow the development of skills and provide spaces where, when learners fail, they turn failure into a constructive learning opportunity. This is one way how education systems can seize the opportunity to capture the students' attention but also realise their potential to learn and grow.

Consequently, since robotics is a new digital tool, teachers need to be supported with the necessary training and mentorship to help them use robotics in their classroom. However, such training should include ways that expose teachers to hands-on opportunities and pedagogies to help them undergo this transformation and use robotics effectively to enhance teaching and learning in their subject area. The optimal importance of having and maximising robotics use in schools in various secondary school subjects has been emphasised.

Notes on contributors

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References

Ardito, G. P., Mosley, P., & Scollins, L. (2014). WE, ROBOT: Using robotics to promote collaborative and mathematics learning in a middle school classroom. *The Middle Grades Research Journal, 9*(3), 73–88.

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*(2), 224–237. doi: https://doi.org/10.1037/0096-3445.130.2.224

Baeten, M., Dochy, F., Struyven, K., Parmentier, E., & Vanderbruggen, A. (2016). Student-centred learning environments: An investigation into student teachers' instructional preferences and approaches to learning. *Learning Environments Research, 19*(1), 43–62. doi: 10.1007/s10984-015-9190-5

Barata, G., Gama, S., Jorge, J., & Gonçalves, D. (2013). Engaging engineering students with gamification. *5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, 1–8. doi: 10.1109/VS-GAMES.2013.6624228

Bers, M. U. (2008). *Blocks to robots: Learning with technology in the early childhood classroom*. New York: Teachers College Press.

Bers, M. U. (2010). The tangible K robotics program: Applied computational thinking for young children. *Early Childhood Research and Practice*, 134–145.

Bers, M. U. (2012). *Designing digital experiences for positive youth development: From playpen to playground*. New York: Oxford University Press.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., & Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education, 94*, 178–192. doi: https://doi.org/10.1016/j.compedu.2015.11.003

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77–101.

Bruner, J. (1983). Play, thought, and language. *Peabody Journal of Education, 60*(3), 60–69.

Bryman, A., & Burgess, R. G. (Eds.). (1994). *Analyzing qualitative data*. London: Routledge.

Camilleri, P. (2017). Minding the gap. Proposing a teacher learning-training framework for the integration of robotics in primary schools in education. *Informatics in Education, 16*(2), 165–179. doi:10.15388/infedu.2017.09

Campbell, A. L., Craig, T. S., & Collier-Reed, B. (2019). A framework for using learning theories to inform 'growth mindset' activities. *International Journal of Mathematical Education in Science and Technology, 51*(1), 26–43. doi: https://doi.org/10.1080/0020739X.2018.1562118

Cannon, R., & Newble, D. (2000). *A Handbook for Teachers in Universities and Colleges: A Guide to Improving Teaching Methods* (4th ed.). London: Kogan Page.

Catania, J. (2019). *ICT C3*. https://eskills.org.mt/en/digitaleducationinschools/Documents/James_Catania_ICT%20C3.pdf

Cohen, D. (1993). *The development of play* (2nd ed.). London, UK: Routledge.

Cojocariu, V.-M., & Boghian, I. (2014). Teaching the relevance of game-based learning to preschool and primary teachers. *Procedia-Social and Behavioral Sciences, 142*, 640–646. doi:10.1016/j.sbspro.2014.07.679

Creswell, J. W. (2014). Research design: Qualitative, quantitative and mixed methods approaches (4th ed.). Thousand Oaks, CA: Sage.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. New York: Harper and Row.

Cutajar, C. (2019). *Computational Thinking: Exploration and Analysis of an ICT Project for Early Years Students*. [Unpublished Master's thesis]. Faculty of Education, University of Malta, Malta.

de Freitas, S. (2006). *Learning in immersive worlds: a review of game-based learning*. http://www.jisc.ac.uk/media/documents/programmes/elearninginnovation/gamingreport_v3.pdf

Demiraslan, Y., & Usluel, Y. K. (2008). ICT integration processes in Turkish schools: Using activity theory to study issues and contradictions. *Australian Journal of Educational Technology, 24*(4), 458–74.

Dewey, J. (1902). *The child and the curriculum*. Chicago: University of Chicago Press.

Dewey, J. (1910). *How we think*. Boston, MA: D.C. Heath & Co.

Dexter, S., Doering, A. H., & Riedel, E. S. (2006). Content area specific technology integration: A model for educating teachers. *Journal of Technology & Teacher Education*, 14(2), 325–345.

Directorate for Learning and Assessment Programs [MEDE] (2020). *Syllabi – Years 9, 10, 11*. https://curriculum.gov.mt/en/Curriculum/Year-9-to-11/Pages/default.aspx

Dweck, C. S. (2006). *Mindset: The new psychology of success* (1st ed.). New York: Random House.

Dweck, C. S. (2010). Even geniuses work hard. *Educational Leadership, 68*(1), 16–20.

Ebeling, D. G. (2001). Teaching to All Learning Styles. *Education Digest, 66*(7), 41–45.

Elliott, S. N., Kratochwill, T. R., Littlefield Cook, J., & Travers, J. (2000). *Educational psychology: Effective teaching, effective learning* (3rd ed.). Boston, MA: McGraw-Hill College.

Engel, S. (2015). *The hungry mind: The origins of curiosity in childhood*. Cambridge, US: Harvard University Press.

Ertmer, P. A., Gopalakrishnan, S., & Ross, E. M. (2001). Technology-using teachers: comparing perceptions of exemplary technology use to best practice. *Journal of Research on Computing in Education*, 33(5).

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, 59, 423–435.

Facer, K. (2012). Taking the 21st century seriously: Young people, education and socio-technical futures. *Oxford Review of Education, 38*(1), 97–113.

Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning, 2*(1), 5–16. doi: https://doi.org/10.2304/elea.2005.2.1.5

Gee, J. P. (2007). What video games have to teach us about learning and literacy. New York: Palgrave Macmillan.

Hannafin, M. J., Hannafin, K. M., Land, S. M., & Oliver, K. (1997). Grounded practice and the design of constructivist learning environment. *Educational Technology Research and Development,* 45(3), 101–117. doi: https://doi.org/10.1007/BF02299733

Hercz, M., Pozsonyi, F., & Flick-Takács, N. (2020). Supporting a sustainable way of life-long learning in the frame of challenge-based learning. *Discourse and Communication for Sustainable Education, 11*, 45–64.

Holdsworth, S., Turner, M., & Scott-Young, C. M. (2018). Not drowning, waving. Resilience and university: A student perspective. *Studies in Higher Education, 43*(11), 1837–1853. doi:10. 1080/03075079.2017.1284193

Huizinga, J. (1955). *Homo Ludens: A Study of the Play Element in Culture*. Boston, MA: Beacon Press.

Hung, C.-M., Huang, I., & Hwang, G.-J. (2014). Effects of digital game-based learning on students' self-efficacy, motivation, anxiety, and achievements in learning mathematics. *Journal of Computers in Education, 1*(2–3), 151–166. doi: 10.1007/s40692-014-0008-8

Jaffe, E. (2020). Mindset in the classroom: Changing the way students see themselves in mathematics and beyond, the clearing house. *A Journal of Educational Strategies, Issues and Ideas, 93*(5), 255–263. doi: 10.1080/00098655.2020.1802215

Julian, J. & Perry, F. (1967). Cooperation contrasted with intra-group and inter-group competition. *Sociometry, 30*(1), 79–90. doi: https://doi.org/10.2307/2786440

Juul, J. (2005). *Half-real. Video games between real rules and fictional worlds.* Cambridge, MA: The MIT Press.

Kohn, A. (1992). *No contest: The case against competition*. Revised Edition. Boston, New York: Houghton Mifflin Company.

Lewis, A. (1992). From planning to practice. *British Journal of Special Education, 19*(1), 24–27. doi: 10.1111/j.1467-8578.1992.tb00398.x

Malone, T. W. (1980). *What makes things fun to learn? Heuristics for designing instructional computer games*. In Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems – SIGSMALL '80 (pp. 162–169). New York, USA: ACM Press.

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction: Conative and affective process analyses* (pp. 223–253). Hillsdale, NJ: Lawrence Erlbaum Associates.

Mataric, M., Koenig, N., & Feil-Seifer, D. (2007). *Materials for enabling hands-on robotics and STEM education*. Conference: Robots and Robot Venues: Resources for AI Education, Papers from the 2007 AAAI Spring Symposium (pp. 99–102). https://www.researchgate.net/publication/221250968_Materials_for_Enabling_Hands-On_Robotics_and_STEM_Education

Mathews, D., Franzen-Castle, L., Colby, S., Kattelmann, K., Olfert, M., and White, A. (2015). Use of word clouds as a novel approach for analysis and presentation of qualitative data for program evaluation. *Journal of Nutrition Education and Behavior, 47*(4), S26. doi: 10.1016/j.jneb.2015.04.071

McCain, T. (2005). *Teaching for tomorrow: Teaching content and problem-solving skills*. Thousand Oaks, CA: Corwin

McNaught, C., & Lam, P. (2010). Using wordle as a supplementary research tool. *The Qualitative Report, 15*(3), 630–643. doi: 10.46743/2160-3715/2010.1167

Ministry for Education and Employment [MEDE] (2016, April 6). The Prince's Trust's xl Programme recognised at MQF Level [Press release]. https://education.gov.mt/en/resources/News/Pages/News%20items/The-Prince%E2%80%99s-Trust%E2%80%99s-xl-Programme.aspx

Mitnik, R., Nussbaum, M., & Soto, A. (2008). An autonomous educational mobile robot mediator. *Auton Robot*, 25, 367–382.

Mohamad, S. N. M, Salam, S., & Bakar, N. (2017). An analysis of gamification elements in online learning to enhance learning engagement. In J. Zulikha & N. H. Zakaria (Eds.), *Proceedings of the 6th International Conference on Computing & Informatics* (pp. 452–460).

Ng, W., & Gunstone, R. (2003). Science and computer-based technologies: Attitudes of secondary science teachers. *Journal of Research in Science & Technological Education, 21*(2), 243–264. doi: https://doi.org/10.1080/0263514032000127266

Ollin, R. (2008). Silent pedagogy and rethinking classroom practice: Structure teaching through silence rather than talk. *Cambridge Journal of Education, 38*(2), 265–280. doi: 10.1080/03057640802063528

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & Education*, 55, 1321–1335.

Owens, G., Granader, Y., Humphrey, A., & Baron-Cohen, S. (2008). LEGO therapy and the social use of language programme: An evaluation of two social skills interventions for children with high functioning autism and Asperger Syndrome. *Journal of Autism and Developmental Disorders, 38*(10), 1944–1957.

Paniagua, A., & Istance, D. (2018). *Teachers as designers of learning environments: The importance of innovative pedagogies*. Paris: Educational Research and Innovation, OECD Publishing. https://doi.org/10.1787/9789264085374-en

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, U.S.: Sage Publications.

Phillips, H. & Condy, J. (2020). How are we really teaching our students? A paradox in pedagogy. *South African Journal of Higher Education, 34*(2), 210–229. doi:10.20853/34-2-3719.

Piaget, J. (1962). *Play, dreams and imitation in childhood*. New York: Norton.

Pratt, S. (2008). Complex constructivism: Rethinking the power dynamics of "understanding." *Journal of Canadian Association for Curriculum Studies, 6*(1), 113–132.

Prensky, M. (2010). Teaching digital natives: Partnering for real learning. Thousand Oaks, CA: Corwin.

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist*, 53, 145–164.

Resnick, M. (2006). Computer as paintbrush: Technology, play, and the creative society. In D. Singer, R. Golikoff & K. Hirsh-Pasek (Eds.), *Play = Learning: How play motivates and enhances children's cognitive and social-emotional growth* (pp. 192–206). Oxford: University Press.

Riding, R. (2002). *School learning and cognitive style*. London: David Fulton.

Rosenstock, L. (2014). Fundamental change in education. In M. Fullan, & M. Langworthy (Eds.), *A Rich Seam. How New Pedagogies Find Deep Learning*. https://michaelfullan.ca/wp-content/uploads/2014/01/3897.Rich_Seam_web.pdf

Salen, K., & Zimmerman, E. (2004). *Rules of Play: Game Design Fundamentals*. Cambridge, MA: MIT Press.

Squire, K. (2003). Video games in education. *International Journal of Intelligent Simulations and Gaming, 2*(1), 49–62. doi: 10.1145/950566.950583

Sullivan, A., & Bers, M. U. (2015). Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education*, 26, 3–20. doi:10.1007/s10798-015-9304-5

Sutton, S. (2011). The preservice technology training experiences of novice teachers. *Journal of Digital Learning in Teacher Education, 28*(1), 39–47. doi: https://doi.org/10.1080/21532974.2011.10784678

Tang, S., Hanneghan, M., Rhalibi, A. (2009). Introduction to games-based learning. In T. Connolly, M. Stansfield & L. Boyle (Eds.), *Games-based Learning Advancements for Multi-Sensory Human Computer Interfaces. Information Science Reference* (pp. 1–17). Hershey: PA.

Terri, F. (2014). *Mathematics achievement with digital game-based learning in high school algebra 1 classes*. Doctoral Dissertations and Projects. http://digitalcommons.liberty.edu/doctoral/794

Uluyol, C., & Sahin, S. (2016). Augmented reality: A new direction in education. In D. Choi, A. Dailey-Hebert, & J. Estes (Eds.), *Emerging Tools and Applications of Virtual Reality in Education* (pp. 239–257). Hershey: Information Science Reference. doi: 10.4018/978-1-4666-9837-6.ch011

Vrain, E., & Lovett, A. (2019). Using word clouds to present farmers' perceptions of advisory services on pollution mitigation measures. *Journal of Environmental Planning and Management, 63*(6), 1132–1149.

Vygotsky, L. S. (1978). *Mind in Society*. Cambridge: Harvard University Press.

Whittier, L. E., & Robinson, M. (2007). Teaching evolution to non-English proficient students by using LEGO robotics. *American Secondary Education, 35*(3), 19–28.

Whitton, N. (2007). Motivation and computer game based learning. *In ICT: Providing choices for learners and learning*. Proceedings ascilite, Singapore. https://www.researchgate.net/publication/249983677_Motivation_and_computer_game_based_learning

Whitton, N. (2018). Playful learning: tools, techniques, and tactics. *Research in Learning Technology, 26*(0), 1–12. doi:10.25304/rlt.v26.2035

Williams, D., Ma, Y., Prejean, L., & Ford, M. J. (2007). Acquisition of physics content knowledge and scientific inquiry skills in a robotics summer camp. *Journal of Research on Technology in Education, 40*, 201–216.

Wood, E. (2013). *Play, learning and the early childhood curriculum* (3rd ed.). London, UK: SAGE.

Wood, R., & Bandura, A. (1989). Social cognitive theory of organizational management. *Academy of Management Review, 14*, 361–384. doi: 10.5465/AMR.1989.4279067

Yuan, J., Kim, C., Hill, R., & Kim, D. (2019). Robotics integration for learning with technology. *Contemporary Issues in Technology and Teacher Education, 19*(4), 708–735.

Zittoun, T., & Brinkmann, S. (2012). Learning as meaning making. In N. M. Seel (Ed.), *Encyclopedia of the Sciences of Learning* (pp. 1809–1811). New York, USA: Springer.