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Mobile Learning to Support Computational Thinking in Initial Teacher Education:
A Case Study

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ABSTRACT

Research on the role of mobile learning in computational thinking is limited, and even more so in its use in initial teacher education. Aligned to this there is a need to consider how to introduce and expose pre-service teachers to computational thinking constructs within the context of the subject area they will teach in their future classrooms. This paper outlines a quasi-experimental study to examine the role of mobile learning in facilitating computational thinking development amongst pre-service teachers in initial teacher education. The study enquires if there are significant differences in grades achieved in computational thinking and programming learning when mobile learning is introduced. Findings showed and reaffirmed the positive influence of the mobile applications on the development of computational thinking amongst the pre-service teachers who participated.

KEYWORDS

Computational Thinking, Mobile Learning, Teacher Education

INTRODUCTION

In his book entitled 'Schools of Tomorrow' John Dewey criticised the institute of higher learning of his day, arguing that education needed to adopt new instructional approaches based on future societal needs (Dewey, 1915). He further contented that schools should reorganize curricula, emphasize freedom and individuality therefore responding to changing employment requirements, emphasising that failure to do so would be detrimental to young people. The same premise is true a century later and in ensuring sustainable educational infrastructures for young people acquiring knowledge, skills and attitudes necessary for their futures, is teacher education (OECD, 2019). Mobile learning is defined as the process of learning mediated by portable, mobile technologies such as smartphones, tablet computers and game consoles (Schuler et al., 2012) and these mobile learning devices combined with computational thinking may be very much at the core of innovation in teacher education. Various educational applications of mobile technologies, termed 'mobile learning', or 'm-learning' are being examined and introduced in schools and in initial teacher education programmes (Burden, Kearney, Schuck, & Hall, 2019). There is also considerable advancements in coding and computational literacy with research demonstrating there is a need for teachers to be prepared to integrate CT into their classroom practices (Prieto-rodriguez & Berretta, 2014).

Like all technological innovations there is considerable interest in exploiting the huge appeal and availability of mobile devices and technologies for their pedagogical uses for the learner, and also

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the necessity to further integrate it in teacher education. For example, as part of the implementation of the Irish government's Digital Strategy for Schools (DES, 2015) a sub-committee of relevant stakeholders and representatives of teacher education was convened by the Implementation Group of the Minister's Advisory Board to further advance the integration of digital technologies in teacher education. The guiding framework proposed for Irish teacher educators in relation to the use of digital technologies in initial teacher education, adopts the PEAT framework of teachers' digital competence by McGarr & McDonagh (2019) and is offered to highlight the range of areas of knowledge and skills required by pre-service teachers to develop professional digital competencies (McGarr & McDonagh, 2019). To support such an approach, it is envisaged that initial teacher education (ITE) programmes should have digital technologies embedded across the initial teacher education experience (Foulger, Graziano, Schmidt-Crawford, & Slykhuis, 2017), supported by teacher educators that are competent in embedding the use of digital technologies in their own practice and suggested areas in relation to this include strategies by Fougler et al (2017). This aligns to the findings from the 2016 National Education Technology Plan by the US Department of Education whereby the categorically argue that it inaccurate to assume that because pre-service teachers are tech savvy in their personal lives they will understand how to use technology effectively in their practice. "This expertise does not come through the completion of one educational technology course separate from other methods courses but through the inclusion of experiences with educational technology in all courses modeled by the faculty in teacher preparation programs" (Thomas, 2016).

Mobile learning and computational thinking are plausible approaches for such strategies and in this paper we introduce a quasi-experimental study to gain an understanding of how mobile learning technologies may support pre-service teachers. The paper introduces the contemporary use of mobile learning technologies in examining computational thinking in teacher education, specifically in regard to computational thinking and programming competencies amongst the pre-service teachers. The results presented demonstrate the computational fluency development in the cohort examined and though not a panacea, may influence teacher education programme design.

LITERATURE REVIEW

Mobile Learning in Teacher Education

Mobile devices serve as a technology that is ubiquitous in nature, portable, and equipped with multimedia capabilities contributing to the learning content delivery to students. For the purpose of this study, mobile devices are portable handheld devices providing a touchscreen interface with computing, information storage and retrieval functionalities, combined with multimedia and communication capabilities, therefore smart phones as well as tablet devices. Smartphones and tablets permit learners to integrate computational, productivity, simulation, exploration and information retrieval tools in a central hub (Handal, Macnish, & Petocz, 2013). Furthermore these devices enable learners and instructors to immerse themselves dynamically in teaching and learning tasks 'anywhere, anytime' with research suggesting that using mobile technologies in the classroom can improve student learning (Campbell, 2013). Moreover, mobile phones used in the classroom can create a more positive learning environment (Chen, 2011).

Research has found that mobile technologies have the potential to enhance mobility in schools, consequently and fundamentally changing the way classrooms are organized across the education continuum including within teacher education programs (Handal et al., 2013; Kearney, Schuck, Burden, & Aubusson, 2012) and when these agents of change are embedded within and across teacher education programmes they are most effective (Mac Mahon, Grádaigh & Ghuidhir, 2016; 2018).

Kearney and Maher further emphasize the importance of putting pedagogy at the centre of mobile learning rather than technology in order to examine its advantages for supporting learning (Kearney & Maher, 2013). In assisting teacher educators understand mobile technology integration in their practice, Schuck et al. coined the term mobagogy to "capture dual interests of the community in mobile technologies and pedagogy" (Schuck, Aubusson, Kearney, & Burden, 2013, p. 4). This approach would inevitably help teacher educators explore mobile learning through their interactions with colleagues in a community of practice (CoP). However programmatic and systematic efforts which explore the integration of mobile learning into preservice teacher education curricula more fully and explicitly are missing (Baran, 2014).

Computational Thinking in Teacher Education

Computational Thinking (CT) is fundamentally an analytical skill used to coordinate and interpret knowledge or data in order to accomplish various practical goals or tasks (NRC, 2010) which extends algorithmic thinking and fluency in working with information technology to competencies which are built "on the power and limits of computing processes, whether they are executed by a human or by a machine" (Wing, 2006). Focusing on conceptual development, Computational thinking, is required to engage in decomposition of the problem, activities such as abstraction, algorithmic design, debugging, iteration, and generalization.

It is important to focus on the importance of learners developing as computational creators as well (Resnick & Robinson, 2017) and computational fluency involves not only an understanding of computational concepts and problem-solving strategies, but also the ability to create and express with—and through—digital technologies: these are essential skills for life in the 21st century. Computational fluency benefits learners as well as educators and in a rapidly globalising world these are skills that will help all citizens understand and appreciate more their geographical, social, cultural and economic contexts (Resnick & Robinson, 2017). Research and literature demonstrates how to incorporate computational thinking into classrooms (Csizmadia et al., 2015; Curzon & McOwan, 2017; NRC, 2010; Resnick & Robinson, 2017; Yadav, Gretter, Good, & McLean, 2017); and pedagogical evidence shows that project-based approaches are the best path to fluency across many disciplines.

The integration of CT for in-service teachers and in pre-service teacher education has been varied and different. There has been substantial focus on professional development in regard to computing and coding for in-service teachers. With research to introduce teachers to computational thinking for in-service teachers being mainly through professional development bitesize courses (Prieto-rodriguez & Berretta, 2014). This work with teachers is mainly short continuous professional development opportunities, embedding computational thinking in their discipline. In influencing teacher perceptions of computational thinking Blum and Cortina examined how a weekend-long workshop introduced teachers to computational thinking and the role of computer science has in regard to a variety of other disciplines (Blum & Cortina, 2007). The results determined that teachers' perceptions of computer science changed significantly to viewing CS as being applicable to an array of disciplines and did no longer focus solely on programming. The workshops also allowed them to present CS in a way that would make it relevant to their students' daily lives.

Research on how to prepare pre-service teachers to embed computational thinking in their future classrooms has been somewhat limited. The application of such being through modules in existing initial teacher education courses (Yadav, Mayfield, Zhou, Hambrusch, & Korb, 2014). Prieto-rodriguez & Berretta (2014) demonstrated that in connecting the pre-service teachers to the skills and resources needed to teach computer science and computational thinking concepts, has a positive impact on their perceptions of computer science. Another study by Yadav et al. (2014) suggested that pre-service teachers who were exposed to CT modules were significantly more likely to accurately define computational thinking. Though limited, many of these results are encouraging. Research has shown that in order for computational thinking to be part of every student's education, all pre-service teacher preparation programmes need to include classes on computational thinking (Barr & Stephenson, 2011). An effective way to implement this would be in examining the effectiveness of mobile learning for computational thinking.

CONTEXT OF STUDY

Participants

This study involved two undergraduate initial teacher education first year cohorts at an Irish University - the BA Mathematics and Education and BA Education (Computer Science and Mathematical Studies) students. The BA Mathematics and Education programme qualifies studies to teach Mathematics and Applied Mathematics, the BA Education (Computer Science and Mathematical Studies) qualify students to teach Computer Science and Mathematics. The two student cohorts were treated as one for the purpose of this study as their first-year programme at University consist of similar modules and both programmes qualifying the graduates to teach at post-primary level.

There are eight students registered in the first-year cohort on the BA Education (Computer Science and Mathematical Studies) programme. There are sixteen students in the BA Mathematics and Education first year group. Twenty of the twenty-four students volunteered to participate in the study. The gender breakdown was 35% male, 65% female with ages ranging from 18 to 19 years old. The pre-service teachers were invited to participate, it was not part of their academic programme. While using volunteers may skew a sample towards these who are naturally more confident, interested or assertive (Cohen, Manion & Morrison, 2013) this was deemed most suitable for the study. There are undoubtedly gains for the pre-service teachers in taking part in this type of research, which may not be immediately apparent, but students coerced into participation would not be likely to contribute a genuine picture of their view and computational competencies.

Theoretical Framework

A guiding framework proposed for Irish teacher educators in relation to the use of digital technologies in initial teacher education, adopts the PEAT framework of teachers' digital competence by McGarr & McDonagh (2019). Aligned with this, and to understand the role mobile learning has on developing computational thinking for pre-service teachers, the design of this study drew on the TPACK framework (Koehler & Mishra, 2009).

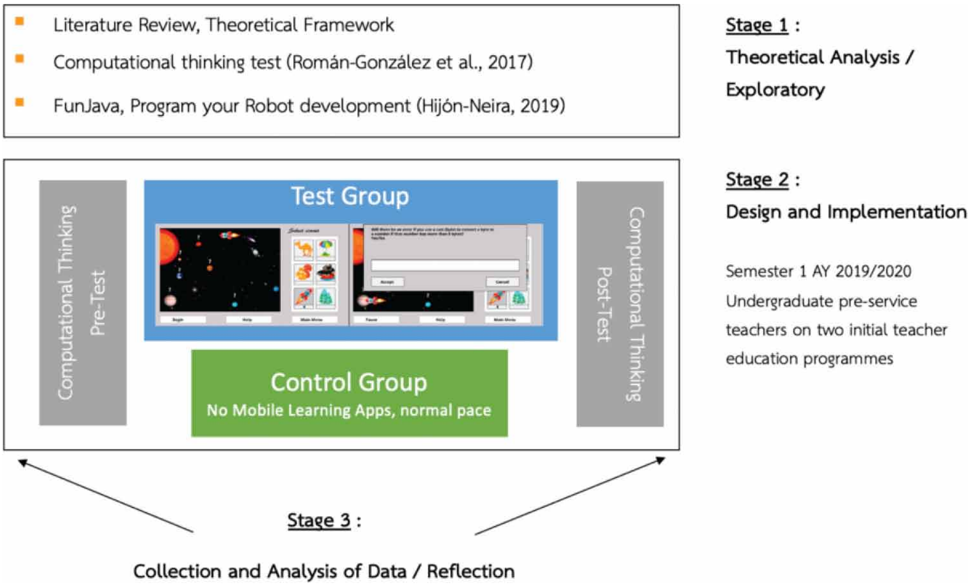
The TPACK framework untangles the range of knowledge need by a teacher for effective content, pedagogical and technological knowledge. Content knowledge (CK) being that needed by the teacher for the subject discipline; pedagogical knowledge (PK) the knowledge required to facilitate student learning and technological knowledge (TK) the knowledge and understanding of technology use in a specific content domain in supporting pedagogical goals. Kale et al. described the computational thinking and TK interconnectedness and relationship (Kale et al., 2018). Accordingly TPACK (technological pedagogical content knowledge) refers to the knowledge and interaction between CK, PK and TK when using technology for teaching and learning including an understanding of the complexity of relationships between students, teachers, content, practices and technologies (Schmidt et al., 2009).

Highlighted by the authors is the necessity to engage in collaborative pedagogical design activities using technology to facilitate the integration of each element of TPACK (Koehler et al., 2011) and in particular when setting the context of specific subject content goals. In this study we embed the CK, of computational thinking, in the TK in the use of the mobile device as Koehler and Mishra maintain that stand-alone, skills based approaches to technology instruction on teacher education programmes do not "provide future teachers with the kinds of experiences necessary to prepare them to use technology effectively in their classrooms" (Koehler & Mishra, 2005, p. 94).

Research Design

The aim of the study was to investigate the role of mobile learning technologies in supporting computational thinking amongst pre-service teachers learning. The principal research question addressed in this study is: What role does mobile learning have in facilitating computational thinking learning for the pre-service teachers. In answering this question we aim to investigate if there are

Figure 1. The study framework

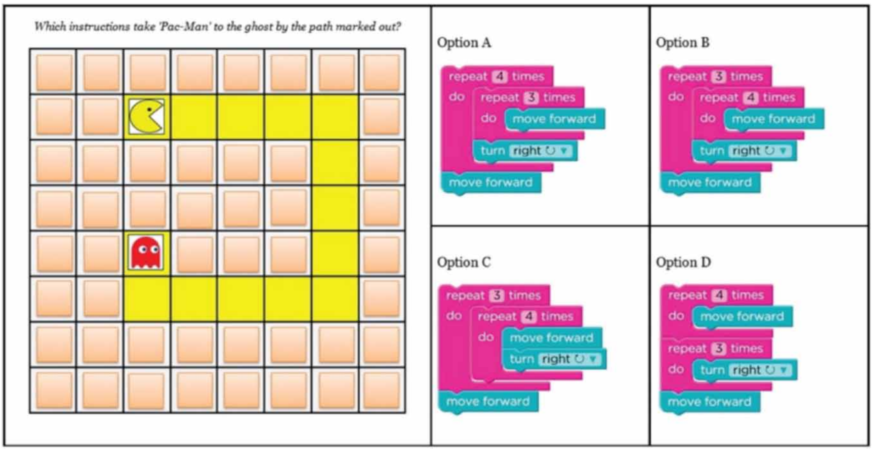


significant differences in grades on computational thinking and programming learning when mobile learning is introduced.

Stage One of this study was the theoretical analysis and literature review. The experiment took place from October to November 2019 of the academic year 2019-2020, during semester one of the pre-service teacher undergraduate programme. The pre-service teachers from the two degree programmes were split randomly into a Control and Test group. The pre-service teachers were invited to compete a pre-test, consisting of the Computational Thinking Test (CTt) and the test group given two mobile learning apps to use at their own pace for five weeks. A post-test was then taken, consisting of the same CTt to evaluate the difference in computational thinking, as depicted in Figure 1 Stage three of the study was the analysis of data.

To evaluate the computational thinking competency amongst the pre-service teacher cohort participating, the Computational Thinking Test (CTt) developed by Román-Gonzalez et al. was adopted. This validated test contains twenty-eight items assessing computational thinking (Román-González, Pérez-González, & Jiménez-Fernández, 2017). The cognitive tasks required to solve the questions include sequencing, completion and debugging. The CTt 'Computational Concepts' are aligned with the CT Framework and with the CSTA Computer Science Standards (Brennan & Resnick, 2012; CSTA, 2011). Each item in the CTt addresses one or more of the following seven computational concepts: Basic directions and sequences; Loops-repeat times; Loops-repeat until; If-simple conditional; If/else-complex conditional; While conditional and Simple functions (all categories four items each.) The questions are presented as either a Maze (23 items) or Canvas (5 items). The answering style is presented in either Visual arrows (8 items) or Visual blocks (20 items). Both the questions and answering styles presented in CTt are also popular in other CT environments (Kalelioglu, 2015). Figure 2 shows a sample question in the CT test where the questions are based on Scratch code blocks and cover a variety of computational thinking areas as discussed. The authors of the test advise that the CTt can be administered collectively in pre-test conditional to measure initial development level of CT amongst students without prior programming experience. The CTt can also be utilised for collecting quantitative data in pre-post of the efficacy of curricula or programs aimed at fostering CT and therefore was applied for this study.

Figure 2. Computational Thinking Test sample question



The mobile learning, serious gaming applications evaluated to adopt in this study where chosen from five which were created to teach programming (Hijón-Neira, 2019). Each apps fosters computational thinking and developed for mobile devices namely: FunJava, GoJavaGo, HC, Program your Robot and SmartJava. The apps were evaluated on a CS vocational training degree and the results provide evidence that students improved their learning of programming (Garcia-Iruela & Hijón-Neira, 2017). In the qualitative evaluation of the apps it was observed the best valuated applications of the five where Program your Robot for the multiplayer mode and FunJava because of the use of a teacher avatar guiding the students. Another further study where FunJava was implemented in a computer programming course with high school students (K10 and K11) showed improvement in their learning of programming (Montes-León, Hijón.Neira, Pérez-Marín, & Montes-León, 2019). Consequently, it was decided to provide the pre-service teachers with FunJava and Program Your Robot for this study. Both the applications introduce and tutor the student teacher to programme in java following the same syllabus structure: firstly basic elements, then structured instructions, subprograms, recursive-ness, arrays and finally files.

Fun Java

This mobile application Fun Java is a Serious Game App for Android devices, which makes the learning of programming in Java language more attractive and easier. The application has a virtual teacher to guide the student through the six well-structured lessons to learn the basics of programming (Figure 3).

The other great functionality of this application is the possibility of answering a series of questions by testing a student (Figure 4, left), or playing between several students in the form of battle (Figure 4, right). The tests are composed of a series of questions in an exam format and after the user sees the grade the student obtained. The ranking of all students participating on the same Android device is also displayed.

Another way to answer questions and establish knowledge of Java programming is through battles. The battles are based on a game 'Trivial Pursuit' where two to four participants can play. To win, it is necessary to correctly answer three questions of each of the six topics, asked by the virtual teacher on the App.

Program Your Robot

The game, Program Your Robot, was the second Android App chosen, allowing the user to learn and improve their programming knowledge in an entertaining way. Taking advantage of everything

Figure 3. Fun Java App lesson included (left) Teacher explaining out loud on the blackboard interactively

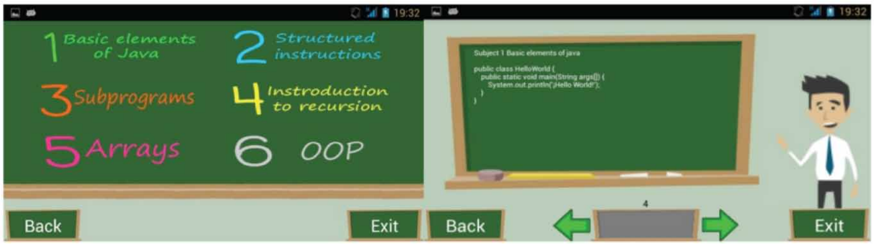
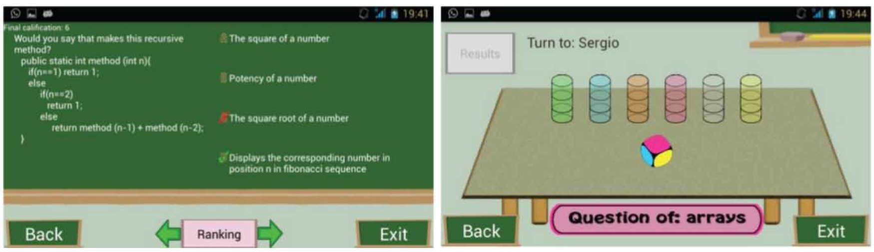


Figure 4. Fun Java on test mode (left) and on quiz mode (right)



that Android offers, this application can be used to play and learn at any time and the App contains two different games.

The first game, called ‘Circuit of Questions’ will try to test the user knowledge about java through questions. For this one can choose one of the 24 levels available, and in each of them the questions will be on different topics, which one sees when choosing the level. The game will consist of a circuit that will go through the avatar and along the way the user will have to meet objectives, for example pick mushrooms in the forest, explore planets in space, or search for treasures in the sea with the pirate ship. However, every time one wants to meet an objective, the user must be able to answer the programming question which will be asked, an example of which is shown in Figure 5.

The second game, called ‘Robot Fight’ demonstrates and illustrates java code, and one can see directly how it affects what the user develops, Figure 6. The robot will perform actions based on coding situations, the user can see the code in these various situations and understand how the code is executing. There are four default robots in the application which test the robots created by the user.

DATA ANALYSIS AND DISCUSSION

The data analysis presented and discussed are both quantitative and qualitative in nature. Participant attrition occurred during the study, as not all pre-service teachers completed a post CTt. Any variability due to people, years or semesters are controlled, however each student becomes his/her own control.

The quantitative analysis carried out examined the participants’ pre CTt results with their post results. From the 20 students who voluntarily started the experiment and took the pre-test, only eight students completed the experimentation and took the post-test. Four were in the control group and four were in the test group. Table I shows the means and standard deviation of the grades for the Control and Test groups. The Shapiro-Wilk tests were used on the two groups, concluding normality in both of them. Furthermore, there is no correlation between the samples. In these cases, the t-test for independent samples was used.

Figure 5. Program your Robot App Question on Space, level 4

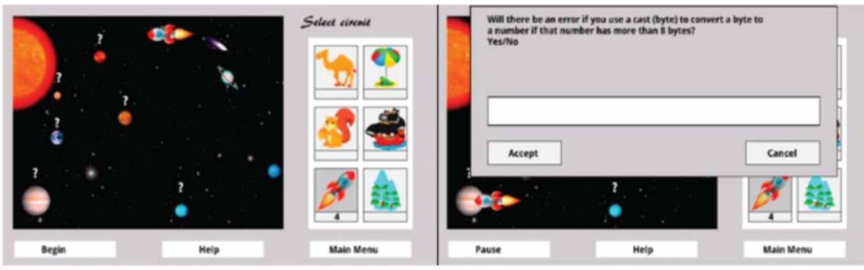


Figure 6. Program your Robot App Battle of Robots mode on the Desert

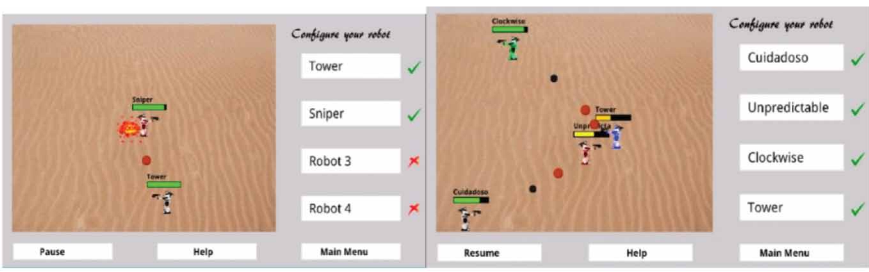


Table 2 shows a comparative between the pre-test and post-test for Control and Test group. There are differences between the grades on computational thinking between the Control and the Test group (the Test group was much higher) but the difference is not significant since p –value is not < 0.005.

Though there are not significant difference there are differences, and what is an important outcome is that the pre-service teachers found it useful and fun in adopting a mobile application in their free time for working on programming and in development of computational thinking development and comprehension. In such a short amount of time it is somewhat difficult to find a significant improvement, but the tendency shows the advancement and progress.

A qualitative analysis phase of the study was administered to all participants at the end of the study to understand more their opinion and views of computational thinking and learning through

Table 1. Statistical Parameters of the Test for the Grades

	Control (n=4)		Test (n=4)	
	M	D	M	SD
Pre-test	6.607	2.567	2.57	0.95
Post-test	5.357	2.351	6.18	1.87

Table 2. T-test Comparative Pre-Post Tests by Groups

	t-Test Analysis	p-Value
Control	t=1.382	0.261
Test	t=-3.000	0.058

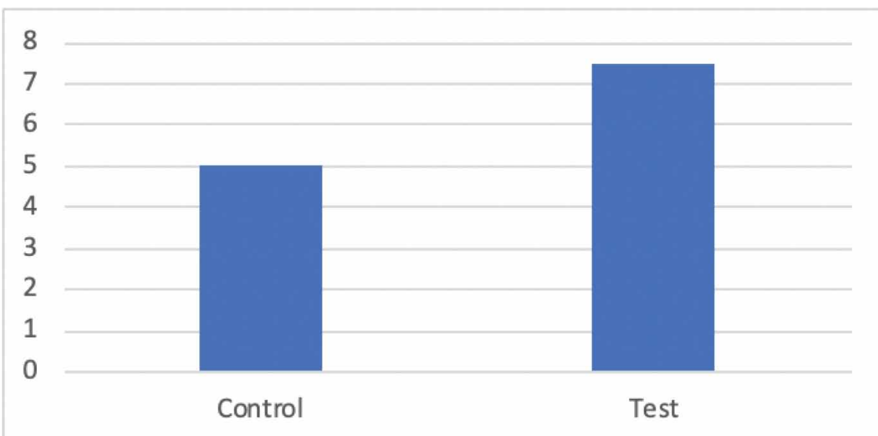
mobile devices. All students were invited to participate. On a likert scale from one to five, from *strongly disagree* to *strongly agree*, when asked if the students liked working with the Mobile apps FunJava and Program your Robot, 37.5% of those students who responded indicated *Undecided* and another 37.5% selected *Agree*. An over whelming 62.5% said they *Agreed* when questioned if they thought Computational Thinking could be increased by using these mobile apps. When asked if they *Would like to have more specifically developed 'computational thinking' mobile apps* 75% of the the pre-service teachers answered that they would. 62.5% of the students who answered indicated that they thought the Mobile Apps they had used contributed to help you in learning programming.

These favourable results reaffirming the positive influence of the mobile applications on the development of computational thinking amongst the pre-service teachers who participated, however the issue of subjectivity is self-rating maybe pertinent here. One of the students provided the following response when asked for any further information or feedback on the study:

The apps definitely got me into 'computational thinking mode' and would be helpful for studying programming as the computational thinking skills require for programming are not really practiced in schools. The apps would therefore be a good supplement to this! (Student 3)

Additional qualitative data was gathered from students in both groups upon completion of the Computational Thinking Test (post-test) and Figure 7 shows results when asked 'How do they think they did on the CTt' on a scale from 0 to 10. The students who used the mobile learning applications, in the Test group, ranked their answer higher than the students who were in the Control group did not use the apps.

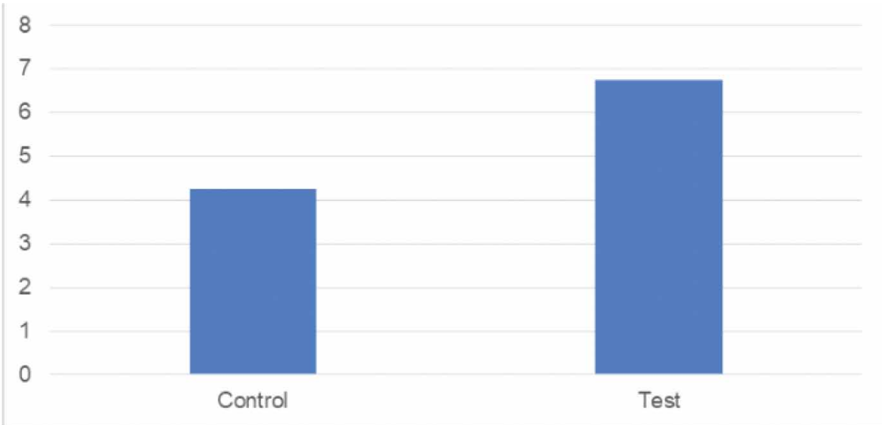
Figure 7. Opinion of pre-service teachers from both Control and Test groups at the end of the experiment about "How do they think they did on the Computational Thinking Test?"



Again, when students at the end of the experiment were asked of their opinion on their use and ability with computers, Figure 8, on a 0 to 10 scale the students who used the mobile learning applications ranked their answer a lot higher than the pre-service teachers in the control group who had just followed the normal pace of the class.

It seems that offering the pre-service teachers mobile learning applications makes them more confident in the way they feel towards technology and they tend to rank themselves higher in having used them. Those students who normally are not prone to embracing technology and mobile devices for learning appear to have a higher appreciation on their capability towards technology after having

Figure 8. Opinion of pre-service teachers from both Control and Test groups when asked about their ability and use of computers in the classroom



used them in their class. It appears that working with the apps empowered these pre-service teachers to subjectively answer this way and the mobile learning applications developed the pre-service teachers ability and self-confidence in embracing mobile devices in their classroom.

The aim of this study was to investigate the role of mobile learning technologies in supporting computational thinking amongst pre-service teachers learning and to investigate if there were significant differences in grades on computational thinking and programming learning when mobile learning was introduced. The results demonstrate that the student teachers were encouraged by incorporating the mobile apps and felt that this facilitated computational thinking development, however the number of participants in the study was relatively small and this invariably affects the statistical analysis.

LIMITATIONS AND FUTURE RESEARCH

There are many avenues to purse in concluding this study, with multiple more strands to explore. This work, being an experimental approach but with such a small number of subjects study in one specific university, has the primary limitation of a narrow focus. While this approach does not facilitate the development of generalisations, it can effectively point out possible results, which require further investigation and validation. The findings generated may not be representative of all pre-service teachers and undergraduate teacher education programmes nationally and internationally, however the findings can potentially offer teacher educators a starting point and guidelines for future programme design and curricula content.

The study provided an introductory approach and future work will naturally invite a greater number of student teachers to participate. The students who did participate where volunteers and the study was not part of their programme nor assessed. Incorporating this approach into the existing education or subject specific modules, which are part of an existing programme, would encourage participation thus yielding to better analysis. Consequently, any future work of a similar study would recommend a study of with a larger cohort and perhaps a longer duration, for example over an academic year.

It could be argued that initial teacher education programmes should teach computational thinking in each subject context through the methodology modules, and introducing this through mobile applications is certainly a possibility. The methodology modules could then be used to expand on preservice teachers' understanding of computational thinking within the context of their subject area. Alternatively the educational technology module/course could also provide computational thinking skill development opportunities. Future research might include this incorporation of computational thinking in the EdTech teaching and additionally pre-service teachers of non-STEM related disciplines should be invited to participate.

CONCLUSION

Our models of practice in teacher education tend to be too closely tied to paradigmatic orientations that are dominant at particular points in time (Zeichner, 1983). Mobile learning has become efficient, useable and ubiquitous in the last twenty years through the design, connectivity and functionality of the devices and in our complex global context, post-Covid environment mobile learning will undoubtedly play a central role (Hall et al, 2020.) Rice and Deschaine (2020) argue that more teacher education programmes should be offered online and are a means to prepare teachers to teach online. With ever-expanding technological options, there is a need for pre-service teacher education programmes to provide student teachers with increased opportunities to learn about how various technologies and our learners.

This paper described an experimental study to examine the role of mobile learning in facilitating computational thinking development amongst pre-service teachers in an initial teacher education programme. The study, with one cohort of student teachers in one university, demonstrated there was differences in grades on computational thinking and programming learning when mobile learning was introduced in cohort who participated. Also of interest was that these pre-service teachers were favourable towards the mobile learning approach. Furthermore, the students who were in the test group (and did use the mobile apps) scored significantly higher at the end of the experiment on their subjective opinion about how they thought that they did on the test; and also on "how do they think they get on with computers?" Concluding from this it might be likely that more mobile learning applications, educative mobile applications, such as those used in this study could foster students abilities and self-confidence towards using this type of technology in their future classroom.

Given the need to graduate teachers with a true understanding of computational thinking (Cuny, 2012; Gretter & Yadav, 2016; Yadav, Hong, & Stephenson, 2016; Yadav et al., 2014) along with the prevalence of mobile learning technologies, there is a necessity for teacher education programmes to incorporate these innovations. Initial teacher education programmes are both central and critical to providing the ideal setting to introduce future teachers to computational thinking. Our education systems are certainly moving in the right direction, nonetheless we need to keep John Dewey's words firmly in our minds, as we seek to advance initial teacher education programmes, educating ourselves and our students for the highly technological world upon which they enter.

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Conflicts of Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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