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Investigating Flipped Classroom and Problem-based Learning in a Programming Module for Computing Conversion Course

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ABSTRACT

This research paper investigates the effectiveness of combined Flipped Classroom (FC) and Problem-based Learning (PBL) teaching approach in a computer programming module. Combined FC-PBL makes use of learning technologies and supports authentic learning in terms of authentic context, multiple perspectives through team work and collaboration. FC involves watching educational videos prior to class session, and using the class session for practical tasks, thus supporting programming skills development. PBL enables authentic learning activities through group work and helps students to develop 21st century skills such as self-direction, collaboration, creativity and innovation. A research case study was conducted that considered a three-stage based delivery of the module that involved traditional, only FC, and combined FC-PBL teaching approaches applied on a number of programming topics. Both the educational and edutainment benefits were analyzed. The results show that combined FC-PBL approach is effective and the knowledge acquired by students improves, in particular, for the weaker students. Only 1.9% of students have scored an assessment mark lower than 40% compared to 28.3% and 24.5% when the traditional teaching and FC-only approaches respectively were used. Overall, a 26.56% increase in the assessment results was noticed when combined FC-PBL was used. The edutainment element was investigated through a questionnaire that assessed learning environment, engagement, learner satisfaction and whether the students have enjoyed learning sessions. The survey analysis shows that the combined FC-PBL approach does aid in the edutainment of mature students and provides an enjoyable learning experience.

Keywords

Flipped classroom, context-based learning technology, problem-based learning, authentic learning, fun e-learning, edutainment, authentic context

Introduction

Edutainment is marriage of education and entertainment and specifically refers to entertainment that is designed to be educational (Aksalal, 2015). An edutainment-based pedagogy needs to be both educational and engaging/enjoyable. Edutainment is very relevant for education today as it aims to provide education with engagement. An important element is that the entertainment should not reduce the value of education and still meet the learning objectives.

Edutainment is especially relevant for subjects such as computer science and mathematics. In computer science education innovative pedagogies are really needed to engage students in subjects like programming as computer science topics (including programming) are not taught at secondary/high school level in many European countries and therefore, students do not have any background knowledge (Vlatko, 2015; Kebritchi, Ab Hamid & Fung, 2007; Hirumi & Bai, 2010; Passey, 2017). As programming is a new area for students in the college, they need to spend a lot of time solving programming problems and the classroom sessions are not able to fully support this. To learn programming concepts and to develop good programming skills one needs to learn to extract the algorithm from the requirements and then translate the algorithm to software code using the syntax of a particular language. To accomplish this a student needs to start with basic problems and programming tasks and gradually practice to complex problems (Winslow, 1996). Various approaches and pedagogical methods have been explored by researchers and educators to overcome the challenges with teaching and learning programming modules. A good approach to deal with programming is to motivate the students by using edutainment-based pedagogical strategies that may involve problem solving practical approaches, authentic context showing how the acquired knowledge will be used in real life, conceptual learning, collaborative learning, authentic activities, self-directed and active learning, practice and learning from failure, increased practical hours.

A relevant pedagogy for edutainment and engagement is constructivism (including socio-constructivism). Constructivist theory of education says that people construct their own understanding and knowledge through experience and reflection. The constructivist pedagogy is based on providing students the opportunities to use active learning techniques to create knowledge (real-world problem solving) and to construct their knowledge through discussion, collaboration and reflection (socio-constructivism). The constructivist pedagogy is suitable for teaching programming and can be quite effective (Wang, Dong & Li, 2012). Constructivism theory also believes in experiential learning which is based on the design of practical labs (kinaesthetic activities). Technology based pedagogies such as game based learning (GbL), flipped classroom (FC) and problem-based learning (PBL) are constructivist approaches that are based on providing education with edutainment.

GbL involves the use of gaming technology for educative purposes where students explore concepts in a learning context designed by teachers. Considering the advantages of games which are fun and engaging, combined with educational field, educational games make students to participate actively in an edutainment environment and help them learn while having fun. Previous research works have shown that game-based learning can have positive effects on important educational factors such as student motivation and engagement (Ghergulescu & Muntean, 2012; Muntean, El Mawas, Bradford & Pathak, 2018), learning effectiveness (Erhel & Jamet, 2013; Zhao, Chis, Muntean, & Muntean, 2018), as well as learning attitude, achievement and self-efficacy (Sung & Hwang, 2013). Moreover, game-based learning has the potential to facilitate the acquisition of 21st century skills such as critical thinking, collaboration, creativity and communication (Qian & Clark, 2016).

FC is a student-centered pedagogy in which students' complete pre-class work (e.g., watching a video clip, searching online for certain information) to gain basic knowledge, and class time is dedicated to activities that promote application and mastery of this knowledge. FC is based on the principles of edutainment as it makes classroom an active learning environment. Lectures are conducted in video format outside of the classroom time and this time is then devoted to discussions, collective and individual feedback, reflections, collaborations, problem-solving, etc. The recorded lecture/video can be completed by students at their own pace. These elements make the flipped classroom approach fun and engaging. The concept of flipped classroom, in association with edutainment, was studied by Guy and Marquis (2016), when students were assigned video lessons and podcasts as opposed to projects prior to class. It was found that these students outperformed those in traditional classrooms, found the actual time in class to prompt more interaction, and thought the class to be more enjoyable, although there was a noticeable period of adaption (Guy & Marquis, 2016). FC also supports the development of new skills such as critical thinking, creativity, communication and collaboration.

PBL is a constructivist pedagogy based on hands-on, active learning collaborative approach that helps students achieve their learning objectives by working on a real-world problem. Due to the active nature of this pedagogy, it focusses on engagement and collaboration while solving problems. PBL empowers learners to conduct research and learn by solving real-world and/or open-ended problems. PBL helps students to develop 21st century skills such as self-direction, collaboration, creativity and innovation, as it puts emphasis on student independence and enquiry, and focuses on students working in groups to find solutions to authentic real-life problems (El Mawas & Muntean, 2018; Larmer, 2014; Rotherham & Willingham, 2010).

Interpreting new information in the context of where and when it occurs, and being able to relate it to what we already know, also develop a better understanding of its relevance and meaning. Therefore, the potential of innovative technologies applied in edutainment such as augmented reality (AR), virtual reality (VR) and virtual labs (VL) has been explored in recent years. These innovative teaching approaches also provide an engaging and enjoyable learning experience and support learning through practicing, hands-on activities and reflection.

AR can engage, educate and entertain learners in a new way. AR adds information or meaning to a real object, integrates contextual data thus enhancing the learning process and provides 3D real models with additional explanations in order to help learners to broaden their knowledge. Several projects (Lai & Wang, 2012) have investigated the use of interactive AR in edutainment. The major benefits of applying mixed realities to educational environments consist in providing young users with a better understanding of concepts, the possibility of resizing and manipulating their augmented representations, personalized learning experience and the possibility to explore the virtual learning space at their own pace (self-directed learning). AR also supports acquisition of new skills such as problem solving, decision making, creativity and communication.

VR is an immersive multimedia 3D simulation of real life that supports interactivity with the created environment and enables sensorial experiences including virtual tastes, sights, smells, sounds and touches. VR has extremely wide applications across a whole range of disciplines, and the technology has reached a sufficient level of maturity to be applied in education in a wide area of topics, such as medicine (Izard, Méndez, & Palomera, 2017), mathematics and geometry (Moyer-Packenham et al., 2016) and engineering (Amirkhani & Nahvi, 2016). VR supports the development of the following skills: imagination, digital literacy, problem solving and risk taking.

VL is a highly interactive multimedia environment that brings learners into a computer-generated world that provides a simulation of the real world to be visually explored in a 3D environment and helps learners to achieve practical skills in an enjoyable and fun way. Numerous projects such as Virtual Engineering Science Learning Lab (VESLL, 2018) and Virtlab Virtual Laboratory (Virtlab, 2018) and research papers (Ghergulescu et al., 2018) propose to develop online interactive learning environments centred on a functional laboratory that supports collaborative problem solving and enhances students' practical skills and digital literacy.

"Interactive learning," "active learning," "knowledge building activities" and "21st century skills" are the key elements of edutainment. All the technology oriented teaching pedagogies discussed above support self-directed, interactive, edutainment environment and develop knowledge building skills required for the 21st century such as critical thinking, problem-solving, communication skills, creativity, imagination, interpersonal skills and lifelong learning attitudes. Knowledge building activities integrated in edutainment fosters 21st century skills that a person should have in order to become a lifelong learner, a person capable to adapt to the new technology developments that are emerging on the market at a growing speed.

Gibbons (2002) defined self-directed learning as "any increase in knowledge, skills, accomplishment, or personal development that an individual selects and brings about by his or her own efforts using any method in any circumstances at any time" (p. 2). Benefits of self-directed learning include: increased ownership of learning, fostering metacognition, increased workplace performance, nurture of appreciation for learning, increased academic achievement, motivation and self-efficacy (de Boer, Donker-Bergstra, Kostons, Korpershoek, & van der Werf, 2013; Guglielmino, 2013; Lavasani, Mirhosseini, Hejazi, & Davoodi, 2011).

This research paper investigates the effectiveness of combined Flipped Classroom (FC) and Problem-based Learning (PBL) teaching approach in a computer programming module delivered as part of a skills conversion Computing course. Combined FC-PBL supports authentic learning in terms of authentic context, multiple perspectives through team work and collaboration. Both the educational and edutainment benefits are analyzed through pre-test, post-test assessments and survey. Knowledge building skills developed through ccombined FC-PBL are also investigated. Although FC and PBL pedagogies have been researched extensively, very few research papers have investigated a combined FC and PBL approach and have assessed the entertainment and educational benefits as this research aims to do.

Literature review

The use of technology in the formal and informal education can improve the learning experience and performance. Flipped classroom (Bradford, Muntean, & Pathak, 2014), interactive educational games (El Mawas et al., 2018a; El Mawas et al., 2018b; Ghergulescu & Muntean, 2010; Muntean, El Mawas, Bradford, & Pathak, 2018; Muntean, Andrews & Muntean, 2017) virtual labs (August et al., 2016; Bogusevschi et al., 2018), enhanced learning experiences through augmented and virtual reality (Cai, Chiang, Sun, Lin & Lee, 2017) are some of the technology enhanced pedagogies that have been applied in education. As this research investigates two self-directed technology based pedagogical approaches such as Flipped Classroom (FC) and Problem-based Learning (PBL) some recent research papers in this domain are discussed next. FC interconnects the home and classroom learning spaces making use of the latest technologies, while PBL enables more authentic learning activities. By freeing class time, the two pedagogical approaches enable the students to spend more time on practical activities, working on real problems and to connect what they learn in school with what they experience in their daily lives. The learning activities become more engaging, as the teachers become facilitators and assistants instead of instructors. Moreover, by using mobile and wireless technologies, seamless flipped learning enables even more authentic and fun learning activities as teachers can include field trips to leverage the diversity of experiences and facilitate the classroom discussion (Hwang, Lai, & Wang, 2015). Flipped classroom makes extensive use of educational videos which is characterised by an edutainment duality, that is to both educate and entertain (Cheng, Safont, Basu & Goebel, 2010). Todays' students have become used to be entertained continuously, and previous research has showed that edutainment with humorous videos can increase students' positive mood, and if the videos are congruent with the subject matter they help increase retention in the short and long term memory (Steffes & Duverger, 2012).

Flipped classroom (FC)

FC is defined as "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (Flipped Learning Network, 2014, p. 1). The main value of flipped classroom is that by doing the instruction online before the class, it frees the class time for students to ask more questions, and for teachers to provide more feedback to individual students, to monitor their progress and to clarify misconceptions (Tucker, 2012). The flipped classroom pedagogy draws on various learning theories such as self-directed learning, active learning, student engagement and motivation, learning styles, cognitive load, and collaborative learning (Bishop & Verleger, 2013). Various research studies have investigated the benefits of applying flipped classroom, in different modules such as computer networking (Chen & Chen, 2014a; Chen, Wang, Kinshuk, & Chen, 2014b), mathematics (Bradford, Muntean, & Pathak, 2014; Love, Hodge, Grandgenett, & Swift, 2014), statistics (Touchton, 2015), programming (Karaca & Ocak, 2017), biology (Jensen, Kummer, & Godoy, 2015), or pharmaceutics (McLaughlin et al., 2014).

Chen et al. (2014b) have conducted a flipped classroom study over 18 weeks with 32 students enrolled in a networking course. The students spent around six hours per week, three hours reviewing videos and three hours attending a synchronous online class. For the synchronous class the authors followed previous recommendations from the literature such as to keep the design simple, to use a second screen for the lesson plan, to provide teacher-directed activities, etc. For evaluation purposes the authors used a survey, interview and system logs analysis. The results have shown that in general the students were satisfied with the new learning approach. However, the interviews revealed several barriers to the full adoption of the FLIPPED model, such as the students' passive learning habits, and the busy schedules of part-time students that were not always able to properly review the study materials in advance of the synchronous class. The main limitations of the study were the low number of participants, and limited control of the experiment as the comparison with the previous two years was only done in terms of metrics such as grades, forum posts and attendance.

Jensen et al. (2015) have conducted a flipped classroom study for a biology course, where the hypothesis was that instructor facilitation is the main causal factor of improvements in student learning in the flipped model. The authors have tightly controlled all other factors, by exposing both non-flipped and flipped groups to the same active-learning instructional materials using the E-5 learning cycle (i.e., engage, explore, explain, elaborate, and evaluate). The first three phases of E-5 correspond to active content attainment and took place in class for the non-flipped group and online as homework for the flipped group. The last two phases of E-5 correspond to content application and took place online as homework for the non-flipped group, and in class for the flipped group. Both groups took 39 class assessments over the semester, out of which 13 assessments were also used in previous years (i.e., the original group used for additional control), while the rest were newly created assessments. In addition, the students had to take 3 unit exams and one final exam. The final exam consisted of 40 low level items, 40 high level items and 24 items to measure students' reasoning. The main finding of the study was that flipped classroom does not have significant benefits over non-flipped classroom, as long as both follow an active learning approach. However, flipped classroom may be a good way to introduce active learning which has significant benefits over traditional passive learning.

Love et al. (2014) have conducted a flipped classroom study for a linear algebra maths course. The students were allocated to two groups based on their availability, without knowing that one group will be taught using the traditional approach and the other group using flipped classroom approach. The results analysis showed that the two groups achieved similar results in the final examination. However, the flipped group achieved a higher increase in grades for the second exam relative to the first exam, as well as for the third exam relative to the first exam. The analysis of a student perception survey showed that 74% of students had a positive attitude towards the flipped classroom approach. Moreover, the results showed that in-class board work helps students to become more comfortable with explaining to classmates and allowed them to develop deeper understanding.

Bradford et al. (2014) have applied flipped classroom to a first year course on introduction to mathematics for computing. Their approach was different, in the sense that only some of the topics were flipped, with all students attending both the flipped and the non-flipped topics. The lecture recordings were delivered through Moodle, and the course was structured so that the videos related to a topic would be viewed in sequence, by enabling watching subsequent videos. The evaluation results showed that the flipped classroom approach improved the students' performance for continuous assessments, but did not impact on exam performance. Overall, the students perceived the flipped topics as being less difficult, and that students preferred flipped over non-flipped topics. However, the research findings were limited by the low number of survey responses and the lack of a control group.

Karaca and Ocak (2017) have applied the flipped classroom approach to a computer science course on algorithms and programming, in order to evaluate its impact on students' cognitive load. The authors have used interactive videos with embedded elements such as quiz questions, and links to other materials. The cognitive load was measured by asking the students to fill a 9-point scale at the end of each face-to-face lesson. The results showed that the students from the flipped group had lower cognitive load than the students from traditional face-to-face classroom. The main limitation of this study was that it was a bit narrow in scope by only looking to students' cognitive load. Moreover, it did not use some baseline testing to check if the daytime and evening students are similar, and did not present other factors that may impact on their cognitive load.

McLaughlin et al. (2014) have applied flipped classroom into a course teaching the basics of pharmaceutics. The students were provided with online videos and reading resources, while the class time was dedicated to student-centred learning activities in the following order: open questions to assess students' understanding, pair and share activities, student presentations and discussion, and individual or paired quiz. The instructor also used micro- lectures to reinforce and if needed to redirect students' learning. The results showed that attendance and final exam results were higher for the flipped classroom as compared to previous non-flipped years. The survey revealed several positive effects, including that over 90% of students perceived the resources as being helpful, that flipped classroom improved their understanding, preparation for exams and their ability to apply the knowledge in the future.

Touchton (2015) has applied the flipped classroom technique to an advanced statistics course. The same videos and assessment project were used for both flipped and non-flipped groups, with the difference that the flipped group watched the videos at home. While the difference in the overall result was small, the flipped group performed considerably better on difficult topics such as: identification of methodology, presentation of results, and interpretation of findings. Moreover, the flipped classroom group gave higher ratings to the class and teacher, and felt they learned more than the traditional group.

A major limitation of all the described research studies is the reliance on grades and the possibility to introduce bias when marking different groups and/or analysing the data.

Problem-based learning (PBL)

PBL is a pedagogy in which students learn by solving real-world or open-ended problems. Savery (2015) defines PBL as "an instructional (and curricular) learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem." (p. 5). PBL is related to other pedagogies such as Project-based Learning, to whom it presents similarities such as the fact that both focus on open-ended questions, provide authentic applications of contents and skills, help build 21st century skills, emphasise student independence and enquiry, and are longer and more multifaceted than traditional lessons or assignments (Larmer, 2014). However, PBL activities tend to focus on smaller scale problems for which pre-existing solutions may exist, and are usually applied within the context of a single module. Various research studies have applied PBL in different modules such as computer science (Şendağ & Ferhan Odabaşı, 2009), software applications (Tsai, Lee, & Shen, 2013), earth science (Lawless & Brown, 2015), healthcare management and paramedic training (Beaumont, Savin-Baden, Conradi, & Poulton, 2014), or production of eBooks (Tsai, Shen, & Lu, 2015).

Şendağ and Ferhan Odabaşı (2009) have conducted an evaluation study with 40 participants that attended the Computer II course. The participating group was randomly split in half into experimental and control groups, after matched pairs were formed based on subjects' prior content knowledge, prior critical thinking skills (CTS) scores, final grades from the Computer I course, Internet use hours per week, and gender. The experimental group was exposed to PBL activities involving ill-structured problem scenarios, while the control group was exposed to traditional teaching. For both groups the teaching was done through the Moodle platform. The results showed that both groups increased their knowledge between pre-test and post-test, but no group outperformed the other. However, the group exposed to PBL achieved statistically higher increase in critical thinking skills than the group exposed to traditional online teaching. The main limitation of the study was the low number of participants. Moreover, the analysis could have been expanded to compare the groups not only on the overall learning outcomes, but also on subsets of questions that measured different aspects such as comprehension and application.

Lawless and Brown (2015) have conducted an evaluation study with 535 urban and suburban middle school students for a science topic on water resources. The students were exposed to GlobalEd 2, a set of technology-mediated PBL simulations that "capitalise on the multidisciplinary nature of the social sciences as an expanded curricular space for students to learn and apply scientific literacies and concepts, while simultaneously also enriching their understanding of the social sciences" (Lawless & Brown, 2015, p. 1). GE2 simulation consists of three phases lasting 14 weeks. Phase one requires the students to use text and web resources to research and identify the key scientific issues of concern, as well as how their assigned country's culture, political system, geography and economy influence their science perspectives. Phase two requires students to work interactively within their class to refine their arguments and negotiate international agreements with the other "countries" sharing them online, in a secure asynchronous format similar to email. Phase three is designed to activate metacognition processes in students as they review what they learned and how they can apply it. The results analysis showed that GE2 PBL simulations had positive effects on students' self-efficacy, their interest in science and their scientific writing.

Tsai et al. (2013) have conducted an evaluation study with 76 first year students from a vocational school that attended a one semester computing course called Packaged Software and Applications. The authors applied PBL and self-regulated learning (SRL) strategies. The students were divided in two experimental groups that attended a blended course and one control group that received traditional didactic lectures. The first experimental group was exposed to both PBL and SRL in the online environment, while the second experimental group was only exposed to PBL. The students were re-evaluated after 36 months to assess the effect of PBL and SRL applied in the first year on their long-term computing skills. The results showed that students exposed to online PBL and/or SRL had statistically significant better computing skills in month 36 than students exposed to traditional lectures.

Beaumont et al. (2014) conducted a study to evaluate how immersive virtual worlds could support PBL. The authors implemented two PBL scenarios in Second Life, for health care management and paramedic training. The first scenario was evaluated with 12 health-care professionals, while the second with ten first year paramedic students. The qualitative analysis of participants' perceptions showed that Second Life PBL simulations provided a rich and engaging environment which enhanced authenticity of the scenarios, though there were issues of access and usability. The main limitation of the study was that it only conducted qualitative analysis, with no quantitative analysis of the other data collected, such as system logs being presented.

Tsai et al. (2015) have conducted an evaluation study with 144 elementary school students to compare three different approaches of teaching: problem-based learning with flipped classroom (FPBL), PBL and traditional teaching. The authors collected both quantitative and qualitative data, including interviews with students and teachers' journal. The results showed that FPBL had statistically higher effect on improving students' learning performance as compared to the other two teaching methods compared.

The main conclusion that can be drawn from the literature review is that previous research studies have mostly focused on evaluating the impact of a single technology-based pedagogical method, FC or PBL versus traditional teaching and learning. While the literature review identified a study that assessed the effects of combining FC with PBL (Tsai et al., 2015), that study was with elementary school students. To the best of our knowledge no previous research study has evaluated the impact of combining FC and PBL with university students. Another conclusion that can be drawn from the literature review was that FC or PBL do not always lead to higher knowledge gain as compared to traditional learning, thus more research studies are needed in order to thoroughly evaluate the benefits of the combined use of these pedagogical methods.

Therefore, the research study presented in this paper focuses on evaluating the effect of combining FC and PBL and applying them in a Software Development module delivered as part of a 3rd level skills conversion Computing course. The research study takes into account some of the limitations identified for previous studies in the literature, by considering both the educational and edutainment aspects into the evaluation.

Case study description

This section provides a description of the conducted research study that aimed to investigate the effectiveness of employing a combined FC-PBL approach to teaching a computer programming module delivered as part of a skills conversion Computing course. In addition, this study assesses the entertainment and educational benefits brought by the combined FC-PBL approach.

There are four main research questions identified and investigated in this research case study:

- Does the combined FC-PBL approach help students to improve their problem-solving skills?
- Do the students' self-directed learning and knowledge building skills enhance?
- Do the students enjoy working in a collaborative environment as part of a team?
- Does the combined FC-PBL approach improve the students' satisfaction?

PBL and FC teaching pedagogies were utilized in a face-to-face learning environment with students studying for a Software Development module delivered as part of Higher Diploma in Science in Computing degree, a one-year conversion course provided by National College of Ireland. 53 mature students (over 25 years old), 19.5% females and 80.5% males took part in the study. The case study was run over a 9 week duration learning session in three stages, each stage having a duration of 3 weeks. Figure 1 shows a summary of the three stages and the pedagogical approaches used during each stage. The first stage involved the use of a traditional approach, namely lectures and practical exercises, to teach programming concepts related to *classes* and *objects*. The second stage involved the use of FC pedagogy to teach programming concepts related to *repetition statements*. The combined PBL-FC pedagogy was used during the third stage for teaching *arrays data structure* related concepts. At the beginning of each stage the students took a pre-test that assessed the students' knowledge on the topics to be covered during that stage. A few students may have had exposure to the topic outside of class, prior to commencing the course, and we wanted to ensure that we compare the results to an accurate baseline. At the end of each stage an in-class assessment (i.e., post-test) was run assessing the students' knowledge level on the studied topics. The assessment components (i.e., pre-tests and post-tests) were developed by a panel of lecturers who have expertise in teaching software development-related modules at both undergraduate and postgraduate levels. Each lecturer proposed questions for the tests and the questions were cross-evaluated by the other members of the panel. The pre-tests and post-tests comprised of seven to ten questions each, depending on the complexity of the questions and the weight of a particular assessment component (i.e., post-test) towards the overall grade for the module. The types of questions used include the application of theoretical concepts to a real-world problem, understanding of code that the students have not seen before, and development of responses to well defined problems. A pair of pre-test and post-test was designed so that while each of the tests had different questions both tests covered the same topic. The questions were developed to evaluate the attainment of the expected learning outcomes. Overall, the tests were each assigned the same maximum score to enable reliable comparison across the different assessments.

The FC teaching approach required students to study basic programming concepts in advance of the class sessions by watching a set of short videos. Students were allowed to watch the videos as many times they wanted. Students were asked to do a short quiz after each watched video that was aimed to provide them feedback. The following programming concepts related to repetition statements were coved by the videos*: for loop, while loop, do-while loop and nested loops.* In return, classroom time was utilized for solving in-class practical exercises, and raising and answering questions. This approach aimed to capitalize on the time spent teaching in the classroom and to use the time to check the students' knowledge on the topic in hand. A student who has watched the videos is more equipped to carry out in-class exercises which in return helps them to develop their conceptual understanding and programming skills. The lecturer's role was to guide students as they applied concepts and engaged with the content. At the end of the 3 week duration FC based learning sessions, an in-class assessment (i.e., post-test) was run in order to assess the students' knowledge level on the studied topics. The learning outcome was analyzed by comparing the pre-test and post-test results.

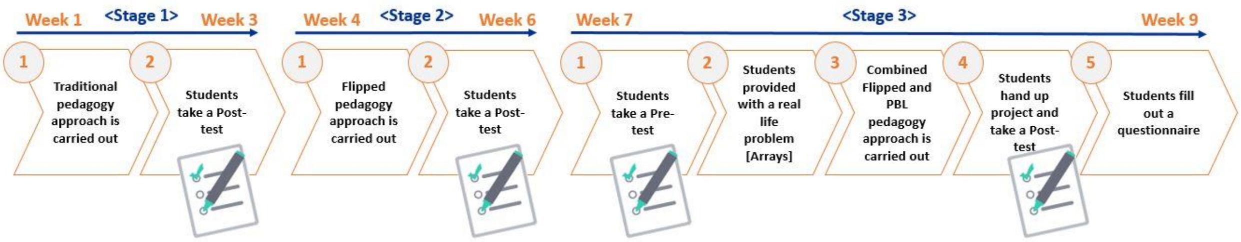

Figure 1. Research methodology

The combined FC-PBL pedagogy applied during the third stage was centered around group work. The students were presented with an open-ended real life problem that required knowledge on arrays data structure and they were required to problem solve by drawing on their own experiences. A video clip on the arrays concept was also provided in advanced of the class session and students were asked to watch it. A short quiz was run just after the visualization of the video. Authentic context based learning of the *array* concept and the use of the arrays in a software application was required in order to be able to identify a solution to the given open-ended real life problem provided in the class. The objective of this teaching strategy was to develop students' critical thinking, reasoning, communication and team work skills. Students were allocated three weeks to collaborate by working in teams and to produce their findings and implement an application that solves the given problem. They were provided with the opportunity to ask questions during class and to try and work out the problem in their groups. Their activity and outcome was delivered as a project and assessed (i.e., post-test). During the teaching sessions, the role of the lecturer was to provide guidance and feedback.

The educational and edutainment benefits of using the combined FC-PBL approach in teaching programming concepts to mature students within an ICT skills conversion programme were investigated. Statistical analysis of pre-test and post-test assessments on concepts delivered through traditional, only FC, and combined FC-PBL teaching approaches was performed. The edutainment element was investigated through a questionnaire, provided at the end of the case study. The questionnaire consisted of 21 quantitative questions grouped in seven categories, namely problem solving skills, team work, self-directed learning, knowledge building skills, learning environment, satisfaction, and engagement as shown in Appendix A. The questions included in the questionnaire were designed following best practices and recommendations from literature on evaluating different approaches in teaching and learning. The questions that assessed the dimensions of engagement, enjoyment and learning were designed following the recommendations from Feng, Chan, Brzezinski, and Nair (2008) and Mac Namara and Murphy (2017). Learning was assessed based on research work presented by Bourgonjon, Valcke, Soetaert, and Schellens (2010). Each question was answered on a 1 to 5 Likert scale (1 – never to 5 – always).

Results analysis

Statistical analysis of the data collected during the three stages of the study is presented and discussed in this section. The main aim of this research is to assess the effectiveness of employing a combined FC- PBL teaching approach. A different teaching approach was employed in each stage of the case study, namely traditional, FC, and combined FC-PBL. Pre-test and post-test knowledge assessment results for the three stages are analyzed and compared.

To be able to answer the research questions presented earlier (see Case Study Description section), in addition to using assessments (e.g., pre-test and post-test), quantitative data was gathered through a questionnaire. The questionnaire collected the students' feedback regrading enjoyment, satisfaction and engagement.

Analysis of learning outcomes and skills enhancement

An important evaluation of the effectiveness of using a combined FC-PBL approach to teaching is to analyse the learning outcome and to establish whether the students skills, and in particular the problem-solving skills have improved. Learning outcome is measured by using two assessments, namely a pre-test and a post-test. Figure 2 shows the assessment results for the combined FC-PBL approach, documented in terms of minimum, first quartile, median, third quartile, and maximum results. It is worth mentioning that an analysis of the pre-test assessment done before FC-PBL was applied show that only 7.5% of students (i.e., 4 students) scored a mark of at least 70.0%, whereas 77.4% of students (i.e., 41 students) got a mark lower than 40.0% (i.e., 40.0% is the passing mark in the Irish education system) and 51.0% of students took a mark of 0. The post-test results analysis shows that 71.7% of students scored a mark of at least 70.0%, whereas only one single student scored less than 40.0%. The results of a paired *t*-test for dependent groups showed that the post-test results (M = 81.0, SD = 18.4) were statistically significant higher than the pre-test results (M = 19.7, SD = 28.2) at α = 0.001 significance level (t (52) = -15.73, p = .000). The post-test results analysis also shows that the combined FC - PBL approach significantly improves the knowledge level.

The problem solving skills acquired through the traditional teaching approach, FC, and combined FC-PBL approach are assessed next to provide a quantitative measure of the effectiveness of the latter approach. Figure 3 shows the post-test results for the traditional teaching, FC-only, and combined FC-PBL approaches, namely minimum, first quartile, median, third quartile, and maximum results. Table 1 presents a summary of the post-test results for the three teaching approaches. The results of a paired t-test showed that the assessment results for combined FC-PBL (M = 81.0, SD = 18.4) were statistically significant higher than the assessment results for the traditional teaching approach (M = 69.7, SD = 33.3) at α = 0.01 significance level (t (52) = -2.78, p = .0075). The results of a paired t-test showed that the assessment results for combined FC-PBL approach (M = 81.0, SD = 18.4) were statistically significant higher than the assessment results for FC only (M = 64.0, SD = 28.5) at α = 0.01 significance level (t (52) = -4.87, p = .000). The results also show that when employing a combined FC-PBL approach, there was, on average, a 26.56% increase in the assessment results when compared to the assessment results achieved for FC only.

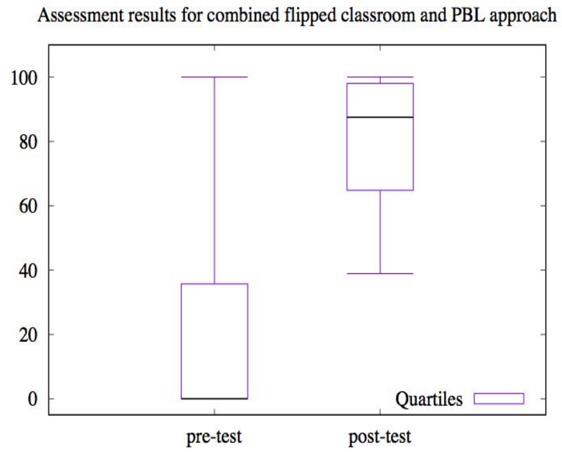

Figure 2. Pre and post assessment results for combined FC- PBL approach

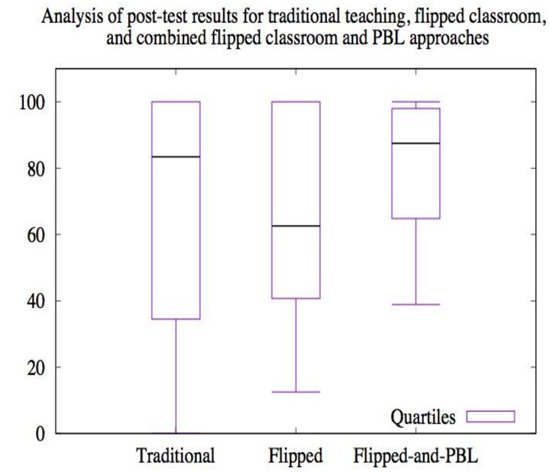

Figure 3. Post-test results for traditional teaching, Flipped (FC), and combined FC-PBL

Table 1. Summary of assessment results for the three teaching approaches

	Min	First quartile (Q_1)	Median	Third quartile (Q_3)	Max	Mean	SD
Traditional	0	34.5	83.4	100	100	69.8	33.3
FC-only	12.5	40.7	62.6	100	100	64	28.5
FC-PBL	38.9	64.8	87.5	98	100	81	18.4

Figure 3 also shows that some of the assessment results for the FC approach are weaker than the assessment results for the traditional approach. However, a paired t-test analysis shows that the assessment results for the traditional approach (M = 69.7, SD = 33.3) were statistically equivalent to the assessment results for FC only approach (M = 64.0, SD = 28.5) at $\alpha = 0.05$ significance level ($t(52) = -1.21$, $p = .229$).

Table 2 provides a breakdown of assessment results for each teaching approach used. In particular, it shows that when the traditional and FC-only approaches were used 28.3% and 24.5% of students respectively scored a mark lower than 40%. In contrast, when the combined FC-PBL approach was employed only 1.9% of students scored a mark lower than 40%. One should note that the difference in the results could be also affected by the fact that each pedagogical approach was used to teach a different programming concept, and some concepts may be perceived by different students to be harder or easier than others.

Table 2. Breakdown of assessment results by results category and teaching and learning approach

	Traditional	FC-only	FC-PBL
Fail results – [0,40) [%]	28.3	24.5	1.9
Average results – [40,70) [%]	11.3	39.6	26.4
High results – [70, 100] [%]	60.4	35.8	71.7

The analysis of the assessment results demonstrates that by using a combined FC-PBL approach the knowledge acquired by students improves. In particular, the combined FC-PBL seems to prove effective in helping weaker students to improve their skills and knowledge due to different reasons such as sessions dedicated to provide guidelines and feedback, peer learning, and team work.

Edutainment analysis

The questionnaire served two main investigative purposes (a) student self-assessment of learning outcomes and skills gained, and (b) to provide a measure of the edutainment aspect of the combined FC-PBL approach. The learning outcomes and skills gained are quantified through questions classified in three categories, namely problem solving skills, self-directed learning, and knowledge building skills. Each of these categories contains 3 questions. Each question was answered on a 1 to 5 Likert scale (1 – never to 5 – always). Figure 4 presents the average responses provided for each question in the aforementioned categories. The results show that all except one question (i.e., Q12) were ranked with a score, on average, of at least 3.5. The aggregated feedback for problem-solving skills, self-directed learning, and knowledge building were rated, on average, at 3.7, 3.9, and 3.7 respectively. Many students considered that they developed their problem-solving skills and knowledge, hence 58.5%, 69.1%, and 57.7% of students rated each question in the problem-solving skills, self-directed learning, and knowledge building categories respectively with at least a 4. The questionnaire results show that the combined FC-PBL approach does contribute to the improvement of students' problem-solving skills, self-directed learning, and knowledge building skills.

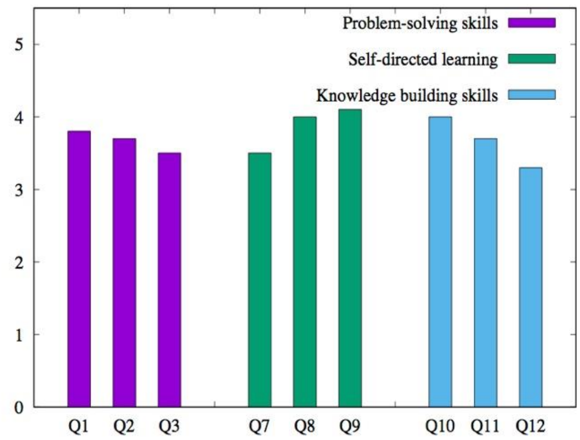

Figure 4. Questions on problem-solving skills, self-directed learning, and knowledge building skills

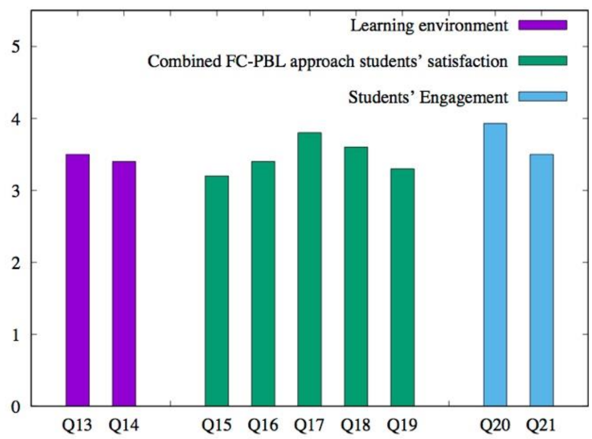

Figure 5. Edutainment assessment: learning environment, satisfaction and engagement

The edutainment component was measured in the questionare via three categories of questions that investigated the students' engagement, and students' satisfaction with the combined FC-PBL approach and learning environment. Figure 5 shows the average responses given by the students for the three categories. The students rated their satisfaction, on average, at 3.4 and their engagement, on average, at 3.7. The agreggated result for the learning environment was rated, on average, at 3.4. The students rated their motivation the highest, on average, at 3.9. These results show that the combined FC-PBL approach does aid in the edutainment of mature students. In particular, 47.6%, 52.7%, and 61% of students provided a rate of at least 4 for the questions in the learning environment, satisfaction and engagement categories respectively.

Overall, the results of the study show that combining FC-PBL pedagogical strategies is effective in teaching programming concepts and supports knowledge acquisition though contextual study and real-life problem solving.

Conclusion

The research paper has investigated the educational and edutainment benefits of combined Flipped Classroom (FC) and Problem-based Learning (PBL) teaching approach in a computer programming module delivered as part of a skills conversion Computing course at National College of Ireland. The combined FC-PBL approach makes use of learning technologies and supports authentic learning in terms of authentic context, multiple perspectives through team work and collaboration.

A 9 week period, three-stage learning process that involved traditional teaching, FC-only, and combined FC-PBL approaches was applied. Pre-test, post-test, and team-based project assessments have been run as part of the course. The results show that when using a combined FC-PBL approach there was, on average, a 26.56% increase in the assessment results when compared to the assessment results achieved, for example, when only the FC approach has been employed. An analysis on the post-test assessment results breakdown for each of the three teaching approaches shows that combined FC-PBL is effective in helping weaker students to improve their skills and knowledge. For example, when the traditional and FC-only approaches were used 28.3% and 24.5% of students respectively scored a mark lower than 40% in the post-test assessment. In contrast, when the combined FC-PBL approach was employed only 1.9% of students scored a mark lower than 40%.

The edutainment element was investigated through a questionnaire, with answers on a 1 to 5 Likert scale (1 – never to 5 – always), which assessed engagement, learner satisfaction and whether the students have enjoyed the learning sessions. The results show that combining FC and PBL pedagogical strategies is effective in teaching programming concepts, supports knowledge acquisition though contextual study and real-life problem solving and provides an enjoyable learning experience. The students rated their satisfaction, on average, at 3.4 and their engagement, on average, at 3.7, and their motivation was rated the highest, on average, at 3.9. Furthermore, 52.7% and 61% of students provided a rate of at least 4 for the questions in the satisfaction and engagement categories respectively, therefore the combined FC-PBL approach does aid in the edutainment of mature students.

The analysis has also shown that the learning assessment results for the combined FC-PBL approach are statistically higher than the results for traditional and FC approaches. This is in line with the research finding of Tsai et al. (2015), which showed that combining problem-based learning with flipped classroom had statistically higher effect on learning performance as compared to PBL and traditional learning approaches. However, the authors did not compare the combined approach with FC. Moreover, their study was conducted with elementary school students, and to the best of our knowledge there is no other comparable research study that evaluated the combined FC-PBL approach with university students. On another side, the analysis showed that there is no statistical significant difference between the FC approach and the traditional approach in terms of learning assessment results. This is in line with the finding of some previous research studies conducted by Jensen et al. (2015) for a general biology course, and Love et al. (2014) for a linear algebra course.

The case study presented in this paper employed different pedagogical approaches to teach programming related concepts on a limited number of topics, namely *classes and objects*, *repetition statements*, and *arrays*. While it can be considered a limitation the fact that the combined FC-PBL has been used only on one topic, the results of this study do show that the blended approach is effective in teaching programming.

The research work presented in this paper is part of the NEWTON project, a large scale European project that designs, develops and deploys innovative solutions for Technology-Enhanced Learning involving delivery of state-of-the-art STEM content. A large-scale pilot that will deliver an entire programming (software development) course over 12 weeks period, through the NEWTELP platform is already scheduled. This pilot will be deployed in three universities across Europe and it will involve over 150 students. The course will use a blend of technology enhanced pedagogies such as game-based learning, flipped classroom and problem-based learning and gamification elements and it will use technology-enhanced learning materials. Educational content used in the case study presented in this paper will be part of the NEWTON programming pilot. While research work on game-based learning has shown that the game helps the students to make sense of the abstract programming concepts, we would like to assess whether a game-based teaching approach enhances the edutainment aspect.

Acknowledgements

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Appendix A

Questionnaire

1. I give permission for the data gathered in this questionnaire to be used for a research study that assesses the effectiveness of PBL and Flipped classroom pedagogies in a classroom environment. Yes □□ No □□
2. What is your gender? Female □□ Male □□
3. What is your age range? 18-21 □□ 21-24 □□ 25-34 □□ 35-44 □□ 45+ □□
4. What course are you currently studying?
5. What category of student do you belong to? School Leaver □□ Mature student □□ Other □□ If other, please specify: ________________________________

Direction: Please select and rate the following questions using the following scales:									
5 – Always	4 – Often	3 – Sometimes	2 – rarely	1 – never	5	4	3	2	1
6. Problem Solving Skills									
Q1. I can apply a variety of problem-solving approaches									
Q2. The project has helped me to develop my problem-solving skills									
Q3. I feel confident about tackling unfamiliar problems									
7. Team Work									
Q4. I enjoy working as part of a team									
Q5. I am willing to forego personal goals for the benefit of the group									
Q6. I am able to express disagreement or disappointment directly									
8. Self-Directed Learning									
Q7. I am comfortable using variety of means to explain programming concepts to others									
Q8. I am willing to draw on my peers as resources									
Q9. I am willing to consider a wide range of learning resources									
9. Knowledge building skills									
Q10. I am able to identify gaps in my knowledge in relation to the learning activity									
Q11. I can easily embed new knowledge by applying it to solve problems									
Q12. I can easily link theory to practice									
9. Learning Environment									
Q13. The learning environment is suitable for me to participate in PBL									
Q14. The Flipped Classroom (videos) is more engaging than traditional classroom teaching									
10. Satisfaction									
Q15. I would like PBL to be used in other modules on the programme									
Q16. I feel that PBL enhanced my experience in this module									
Q17. I like watching the lessons on video									
Q18. I like taking my quizzes online using Moodle									
Q19. Short flipped learning videos are more effective than traditional face-to-face lectures									

11. Engagement					
Q20. I felt motivated to complete the PBL Project					
Q21. I am satisfied with the work I did on the PBL project					