IMPROVING STUDENTS' LEARNING EXPERIENCE IN A PROGRAMMING MODULE WITH MULTIMEDIA ASSISTED MATERIALS AND PROBLEM-BASED LEARNING

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Abstract

This paper investigates the impact of combined Multimedia Assisted Learning (MAL) and Problem Based Learning (PBL) teaching approaches on students' learning experience when applied in a computer programming module. Europe is experiencing a significant decline of students' interest in the field of science which has become a major concern. Engineers and technicians are struggling with the declining public recognition which is leading to shortage of scientific and technological staff. The amalgamation of education with different innovative technology based approaches is the solution to deal with this crisis. A case study was conducted as part of the NEWTON Project Large-scale Programming Pilot deployed in Dublin City University (DCU), Ireland. The MAL and PBL teaching approaches were introduced as part of EM108 Software Development for Engineers module to 1st year undergraduate students to help the them to understand better the programming concepts. Overall 84.38% of total students scored above 80 (out of 100) in the problem-solving project whereas only 6.25% of the students scored less than 39 out of 100 marks. This research studied the students' perceived learning experience and their skills confidence on Team work and Problem Solving. 69.83% of students were satisfied with their learning experience in the programming pilot. Only 11.03% of the students disapproved that the combined MAL and PBL teaching approach helped them to enhance their problem-solving skills and 11.76% of students did not agree that the applied teaching methodology inculcates team work spirit. Overall, the case study has shown that MAL and PBL teaching approaches did help the engineering students and improved the learning outcome for computer programming module.

Keywords: problem-based learning, technology-enhanced learning, multimedia, Programming, STEM.

1 INTRODUCTION

Psychologists and education practitioners have recognised that each student has a different approach to learn and to process information, suggesting a need to restructure the teaching and learning experience in order to fit student needs. Europe is experiencing a significant decline of interest in science which has become a major concern as engineers and technicians are struggling with the problem of declining public recognition hence leading to shortage of scientific and technological staff. The amalgamation of education with different innovative technology based approaches is the solution to deal with this crisis.

Computer assisted learning as a medium to deliver knowledge also known as e-Learning has become an extremely popular topic in the field of education. However, e-Learning replicates the conventional and traditional classroom experience where only the medium of delivering the information and knowledge is digitalized but not the teaching protocol. In today's digital world it is essential for students to learn certain degree of core skills like programming, analytics and procedural logic. Often students belonging to field of technology find the basic concepts of programming and logic difficult to comprehend which has led to higher dropout rates specially in European countries [1].

The journey of developing and cultivating efficient computer programming skills starts by understanding the logic behind the algorithms and then be able to translate the logic to a syntax which adheres to a desired programming language structure [2]. Hence, the concept of constructivist pedagogy comes into consideration which is a philosophical viewpoint that instructs the students to learn through a problem, working cooperatively and collaboratively in teams to seek solutions to real world problems. Researches in the field of education have put forward concrete evidence that introduction of constructivism can rewire the entire teaching-learning experience by making the process creative, interactive and engaging

[3]. The constructive theory of education empowers the students to construct knowledge and intelligence through experiences which can be tangible and intangible in nature. The constructive theory of education is considered to enhance significantly the cognitive flexibility and cognitive functionality of students who apply these principles in their process of learning and achieving knowledge [3]. In the field of technology, the constructivist pedagogy has been proven to be an effective approach to teach computer programming concepts and procedural logic efficiency [2].

Problem-based Learning (PBL) is a subset of constructivist pedagogy where the philosophy behind this pedagogy is that the inception of the learning process should be a problem, complexity, or a puzzle that the student wishes to solve. Hence, the problem in focus acts as a catalyst to increase students' curiosity to solve the problem. A Multimedia Assisted Learning (MAL) teaching approach recommends students to watch videos in the class or outside of class session in order to attain pre-context basic knowledge before the teacher introduces the concepts or to reinforce the topics taught during the class session. PBL and MAL empower the students to make classroom a platform to discuss the gained knowledge and ideas thus building clear concepts. These approaches also enable the teacher to provide assistance to the students which pivots the concept of tradition class room model from a teacher centric model to a student centric model. The primary role of the teacher is to act as a facilitator to promote the self-directed learning that will help the students to develop autonomous learning.

In the context of the NEWTON project, this paper describes the infusion of computer science education with Multimedia Assisted Learning (MAL) and Problem-based Learning (PBL) which can inculcate clarity and motivation in students toward STEM education. The MAL and PBL based educational materials part of the programming pilot were delivered through the NEWTELP platform that was used during the lab sessions in two consecutive weeks as part of EM108 Software Development for Engineers module at Dublin City University. Students were first given a series of videos that cover the knowledge related to "array" concept. Then, they worked in groups of 3 to solve a PBL project, called "Morra Odds and Evens". The project required a C++ code to be written by each team as part of the application to be developed and a report to be submitted. After they finished the project, they were asked to fill in a questionnaire with questions on different aspects such as affective state, problem solving skills, and team work.

The remainder of the paper is divided into five sections. Section 2 presents literature review on MAL and PBL teaching approaches, section 3 explores the case study and the research methodology, section 4 contains the results analysis of the case study and section 5 concludes the research work.

2 LITERATURE REVIEW

The application of technology in education can improve the learning experience, performance and cognitive development of the students. Concepts like multimedia assisted learning, problem-based learning, augmented reality, virtual reality, adaptive and personalised learning and educational games are some innovative technology enhanced teaching approaches that can transform a tradition classroom experience [4, 5, 6, 7].

This research paper is centred around Multimedia Assisted Learning and Problem-Based Learning. Example of research papers that have used these approaches are discussed and compared next. The two teaching approaches work differently. PBL focuses on helping students to develop new skills and knowledge by encouraging them to find solutions for a puzzle or problem whereas MAL makes use of educational videos that make the learning experience more student centric and the teacher acts as a facilitator of knowledge.

Multimedia Assisted Learning (MAL)

MAL amalgamates the technology, visualisation and video content to make the learning more active, dynamic and interactive and to increase student's attention span and engagement [8]. There are several reasons that make MAL as a benchmark for the future of innovative teaching learning experience such as teachers can function as learning designers by orchestrating different multimedia assisted outfits to deliver knowledge to students; MAL activities are supported by multiverse educational theories such as Bloom's taxonomy, student centred learning theory, self-regulated learning, self-determination theory etc. [9].

MAL also empowers the students to access various videos about specific course topics that should be studied as part of each class, using any device irrespective of their location. In-class activities can employ the use of available multimedia whereas the out-class activities can be coordinated through learning management systems such as Massive Open Online Courses (MOOCs) and Personal Learning

Environments (PLEs) [10]. A MOOC is generally offered through a sophisticated online social network where the users of MOOC can negotiate over collaborative topics and goals making the participation more emergent, dynamic and diverse [11]. Fengfeng Ke [12] introduced the concept of splitting the students in groups of three categories: cooperative, competitive and individualistic. Each group is provided with relevant video materials. After scrutinizing 122 studies he concluded that collaborative approach is much more efficient in terms of productivity and learning.

Longo at al. [11] evaluated the advantage of MOOC for STEM education by using a competition-based problem-solving approach to stimulate the interest of students in maths. The results concluded that competition is a significant motivational incentive to improve the learning of the concepts of mathematics by employing the use of appropriate organised tools. This notion of using competition as catalyst to promote learning of new concepts was also investigated by Vidya in [13] where it is highlighted that competition can induce stress degrading the learning process and understanding of the concepts.

Karara and Ocak [14] worked on a research that aimed to measure and compare the cognitive load of students in presence and absence of multimedia based materials for assisting the teaching of a computer science module that covered programming and algorithms concepts. The researchers employed interactive quizzes and videos. A 9-point scale was used to measure the cognitive load at the end of face-to-face lesson. The analysis of the results has shown that the group of students that was exposed to multimedia materials was skewed towards less cognitive load than those students from traditional group. However, the study failed to capture the impact of other factors causing the cognitive load which make the conclusion of analysis less accurate.

Touchton [15] applied the MAL teaching approach in field of advance statistics. Students were divided in two groups where one group was exposed to multimedia content and assessment project at home, while the other group access multimedia materials in the classroom environment. The multimedia content and the assessment project were the same for both the groups to eliminate resource biasness. The difference in the overall result achieved between the groups in this study was small, where the group which consumed the multimedia content at home performs better than the other group that studied the material in the class. The students agreed that they prefer the use of multimedia assisted learning as a better pedagogy technique than the tradition classroom.

Bradford et al. [16] conducted an experiment on the first year "Introduction to Mathematics for Computing" module to investigate the use of videos in advanced of the class session and its relationship with student learning. Videos were developed and provided for a number of core maths topics. A traditional lecture approach was utilized for the remaining topics. Results indicated that educational videos provided in advance of the class session improve learning and students are in favour of this teaching approach.

In all of the above discussed studies a major issue is that only achieved grades are considered as a diagnostic for the learning analysis which could induce a bias as other factors that can contribute to the experience of learning and knowledge gain are not considered in the evaluation.

Problem-based Learning (PBL)

PBL was introduced at the McMaster University Medical School, Canada, in the year 1969 [17] to address the problem of students' lack of motivation and the low pass rates. According to Duch et al. [18], PBL is an instrumental method that instructs the students to learn through a problem, working cooperatively and collaboratively in teams to seek the solutions to real world problems. The problems invoke curiosity and introduce a topic and motivate the students to study. The underline philosophy behind PBL is that the inception for the learning process should be a problem, complexity, or a puzzle that the student wishes to solve. Some researchers [19] have highlighted that PBL can empower the student by motivating and hence reducing failure and dropout rates. PBL develops students' learning by inculcating skills like teamwork, problem solving, project planning and hands-on practical skills.

PBL as a teaching approach was applied in modules such as software engineering, UML language, project management, mathematics and computer programing. The "Multi-Role Project" (MRP) considers the learning activity as a role-playing problem-based learning and it was applied on two projects: a learning project and an engineering project [20]. The project considers the following five principles that provide a framework to mentor students: fair distribution of work; constant solicitations within the team; strategic and constant improvement; positive symbiosis; open communication and content management. The results have shown that MRP helped students to achieve essential professional knowledge and skills, self-development of near-real-world experience in professional scenarios and to develop their skills to work in collaboration with the teams. In this study potential bias is induced as the

evaluation is performed by the MRP researchers also the authors of the study. Certain evaluations are carried out by teachers hence it contains fair amount of subjectivity [20].

Kuo et al. [21] amalgamated human-computer interaction systems with problem-based learning to study the effects and implications of this novel approach on the students from engineering department and design department. This approach had a significant effect on the overall students' motivation, students learning performance and students' enjoyableness to learn STEM topics. The striking feature of the research is the difference in the results achieved by the engineering students and design students. This approach significantly improved the performance of engineering students whereas the approach had no significant effect on the performance of students from the design department. Other limitation of this study is the lack of age diversity under observation and the small size of participants [21].

Chis et al. [2] investigated the effectiveness of combined Flipped Classroom (FC) and PBL teaching approach in a computer programming module in order to support authentic learning in a computing conversion course for mature students. The edutainment benefits were investigated in terms of learning environment, engagement, learner satisfaction and whether the students have enjoyed learning sessions. The results analysis has shown that the combined FC-PBL approach does aid in the edutainment of mature students and provides an enjoyable learning experience.

A major limitation diagnosed for all the described research studies is the reliance on subjective views of the participants and evaluators which certainly may introduce bias when creating the groups or during the analysis of the data.

3 CASE STUDY AND METHODOLOGY

This section presents a description of the case study that investigated the combination of MAL and PBL teaching approach as part of the NEWTON Project large-scale Programming pilot.

The NEWTON Project, funded by EU Horizon 2020, aims at developing a networked platform to assist the delivery of innovative learning approaches, such as PBL, MAL, game-based learning, gamification and technology-enhanced learning (TEL) materials which include virtual labs, virtual reality, augmented reality, multimedia and mulsemedia content and fabrication labs [22,23,24,25, 26]. Various TEL applications and educational materials were developed targeting different STEM subjects for primary, secondary and 3rd level education. Moreover, an innovative versatile Learning Management Platform, i.e., the NEWTELP Platform, was developed to provide support and integration of such TEL materials.

The Programming large-scale pilot was deployed in Dublin City University, Ireland, as part of the EM108 Software Development for Engineers module for 1st year undergraduate students from the Engineering Department, during Semester 2 of the 2017/2018 academic year. TEL materials including serious games, multimedia content, as well as PBL were utilized. The whole educational content, including traditional materials such as lecture slides and lab manuals, TEL materials, tests, quizzes, and questionnaires, were delivered through the NEWTELP Platform [27, 28].

This paper presents an analysis of the combined MAL and PBL teaching approach that was deployed during the Week 7 and 8 of the semester, aiming to help students with the study of the "array" concept in C programming language. First, students were given the multimedia assisted learning material, i.e., a video on the knowledge related to "array" (see Figure 1). The video focuses on three aspects, i.e., the definition of the "array" concept, how to use an "array" (including declaration and initialisation of an array and access of the array elements), and a useful example of how to use an "array" object in a piece of code Then, students were asked to work in a group of 3 on a PBL project, which requires the development of an application to allow a user to play repeatedly the "Morra Odds and Evens" game with a computer. The project required the use of the array concept in the application. Students mainly worked on the project during the lab sessions (2 hours each week) during the two-week period. Students were allowed to discuss freely among themselves and utilize all kinds of resources to solve the problem and develop the application. At the end of the second lab session they submitted the source code of the developed application on a group basis, as well as an individual project report written by each of student separately. The report described student's own contribution to the project. The PBL project was marked separately for each student, based on the quality of their group's application, the quality of the individual project report, as well as the contribution portion of each student towards the development of the application.

After that, the students answered a questionnaire that contains questions assessing student's learning experience with the MAL material and the PBL project. Different aspects such as affective state, problem solving skills, and team work were analysed.

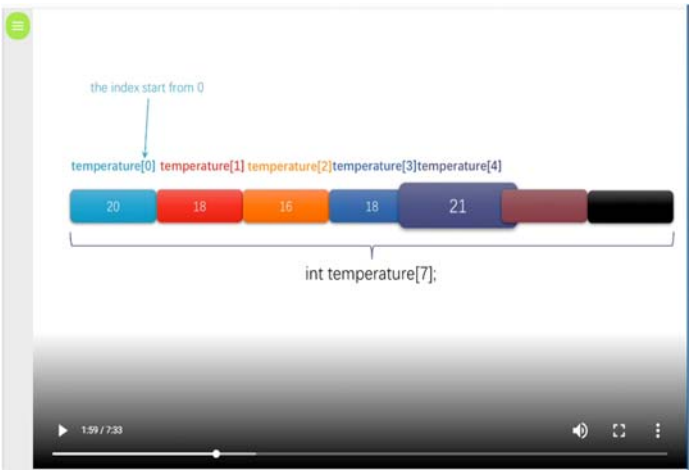

Figure 1 Screenshot of the "Array" video

4 RESULTS ANALYSIS

This section presents the results of the questionnaire that assessed MAL and PBL approaches integrated as part of the NEWTON Programming. The students were asked to answer ten questions that assessed the learning experience, problem solving and team work skills. This section also presents the assessment results for the PBL project assigned to the students.

4.1 Questionnaire Analysis

The questionnaire consisted of 10 questions with answers on a 1-5 Likert scale (e.g. strongly disagree, disagree, neutral, agree strongly agree). The questions were categorised in three groups corresponding to Team Work, Problem-Solving skill and Learning Experience and are presented in table 1.

	Category	**Question**
Question 1	Team Work	I am willing to forego personal goals for the benefit of the group
Question 2		I enjoy working as part of a team
Question 3	Problem Solving skills	The project has helped me to develop my problem-solving skills
Question 4		I can apply a variety of problem-solving approaches
Question 5		I am able to express disagreement or disappointment directly
Question 6		I feel confident about tackling unfamiliar problems
Question 7	Learning Experience	MAL and PBL project made me more interested in this Programming course
Question 8		PBL project was really interesting
Question 9		MAL and PBL project was boring
Question 10		I would prefer to learn without this MAL and PBL project

Table 1 Survey Questions and their Classification into 3 Groups

Team Work

Team Work skill was evaluated by Questions 1 and 2 and the distribution of the answers is presented in Figure 2 and Figure 3. The purpose was to understand how the combined MAL and PBL approach helped the students to develop the team spirit among themselves. Team Work feature was analyzed in terms of number of "Strongly Agree" and "Agree" answers given by the students. Overall, the students' perception on Team Work was that 63.24% of the students were confident that the PBL project helped

them to develop team work spirit and only 11.76 % of students answered disagree or strongly disagree indicating that the project never helped them to develop the team work spirit.

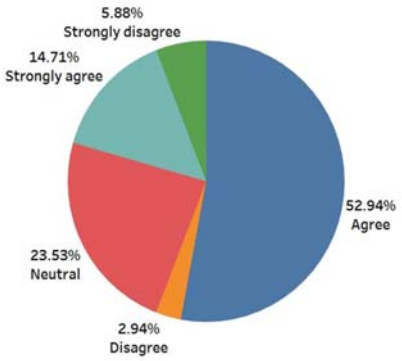

Figure 2: The Answers Distribution for Question 1

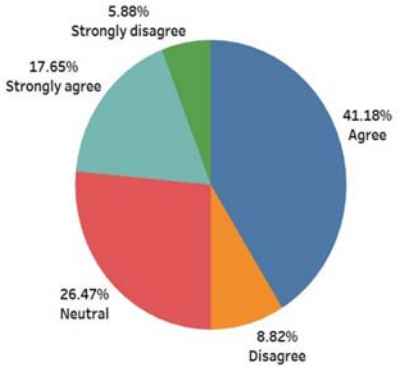

Figure 3: The Answers distribution for Question 2

Problem Solving

Problem solving skills was evaluated through Questions 3 - 6 and the distribution of the answers provides is presented in Figures 4 - 7. An analysis of the students' response in terms of "Strongly Agree" and "Agree" shows that 62.49% of the students believed that the project helped them to develop problem-solving skills and only 11.03% of students disagree or strongly disagree with this affirmation.

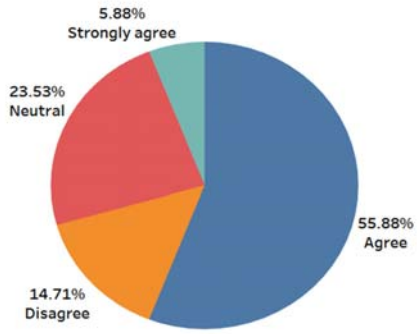

Figure 4: The Answers Distribution for Question 3

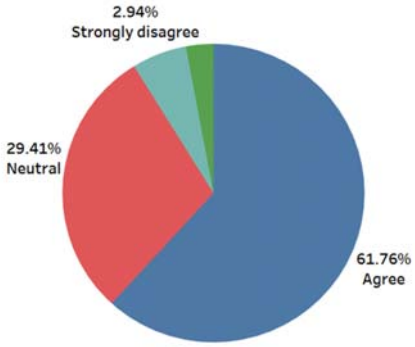

Figure 5: The Answers Distribution for Question 4

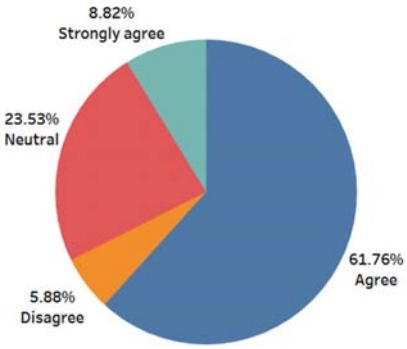

Figure 6: The Answers Distribution for Question 5

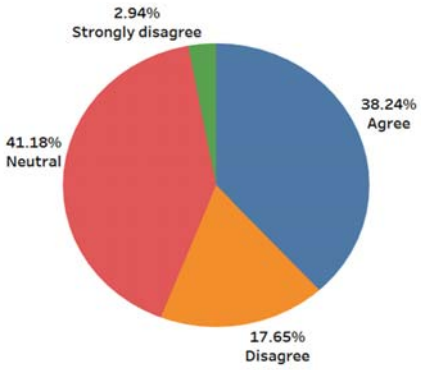

Figure 7: The Answers Distribution for Question 6

Learning Experience

Learning experience was evaluated in "Questions 7 – 10 and the answers are illustrated in Figures 8-11. Overall the students' perception was that 69.83% "Strongly Agree" and "Agree" that the MAL and PBL teaching approach enhanced their learning experience and they were satisfied with the PBL project.

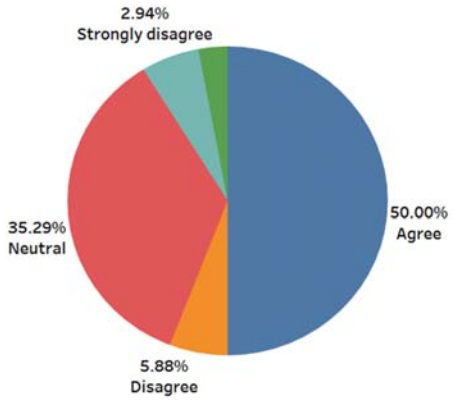

Figure 8: The Answers Distribution for Question 7

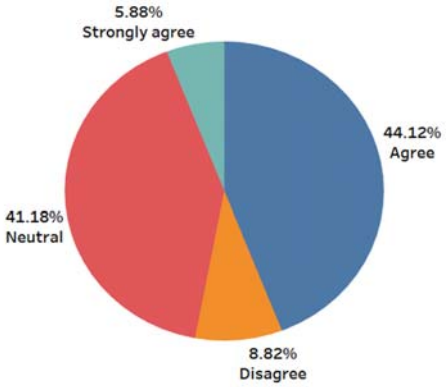

Figure 9: The Answers Distribution for Question 8

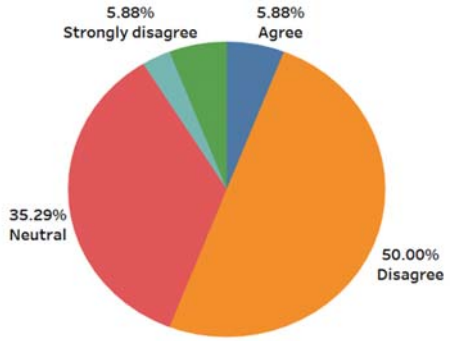

Figure 10: The Answers Distribution for Question 9

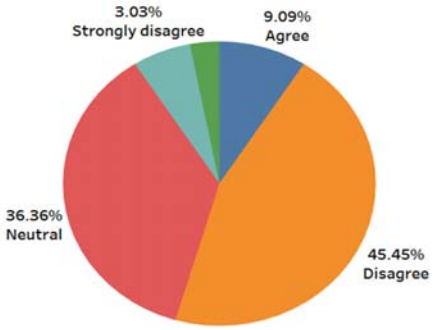

Figure 11: The Answers Distribution for Question 10

4.2 PBL Project Marks Analysis

The analysis of the PBL project marks is presented in Table 2. The marks received by the students were divided into different bins. Based on the distribution of the marks we concluded that the vast majority of students (84.38%) scored 80 marks or above and only 6.25% of the students have failed the project (<40 marks). These results show that the MAL and PBL approach helped the students to learn the array concept and to be able to apply the concept on a real word problem.

No	Number of the Students	Marks Range
1	2 (6.25%)	20-39
2	1(3.13%)	40-49
3	0 (0%)	50-59
4	2 (6.25%)	60-69
5	0 (0%)	70-79
6	4 (12.50%)	80-89
7	23 (71.88%)	90-100

Table 2: PBL Project Marks Distribution

5 CONCLUSIONS

The research presented in this paper has investigated the impact of multimedia assisted learning materials and PBL on student's subjective feelings and learning outcomes in a computer programming module. This study was conducted as part of the NEWTON Project Large-scale Programming Pilot deployed at Dublin City University, Ireland. The introduction of the computer programming pilot in the software development lab sessions of the Engineering students significantly helped them. Overall 84.38% of the students scored marks above 80 in the PBL project whereas only 6.25% of the students scored below 40 and failed the project. This research has also studied students' perception on team work and problem solving skills as well as their learning experience. Overall, 69.83% of students were satisfied using MAL- PBL teaching methodology applied in the programming course. Only 11.03% of the students disapproved that this methodology helped them to enhance their problem-solving skills and 11.76% of the students did not agree on the notion that the pilot inculcates team work spirit.

In conclusion, the analysis unbiasedly suggests that combination of multimedia assisted learning materials and PBL pedagogy significantly help the students to facilitate construction of better understanding of programming concepts

Future research work will analyze the impact of the game based learning teaching approach that was applied as part of this plot on other programming topics.

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