IMPROVING LEARNER KNOWLEDGE AND EXPERIENCE BY EMPLOYING NEWTON PROJECT SERIOUS GAMES IN PROGRAMMING COURSES

This paper presents and discusses the results of a large-scale study of the effect of game-based learning in Programming courses. The study is part of the EU-funded H2020 project NEWTON and employs NEWTELP, a novel platform for distance learning which was designed and implemented by the project. Several educational games, also created within the NEWTON project were deployed in the NEWTELP platform and were offered to over 200 students from three European universities. Apart from the games, the platform also stored lessons, tests and questionnaires that support both technology-enhanced learning and evaluation. The paper discusses the study results and shows how by employing educational games in Programming courses, both learners' knowledge levels and their reported learning experience improves.

Keywords: game-based learning, STEM, Programming course, learner knowledge

INTRODUCTION

Current pedagogical approaches in science, technology, engineering and mathematics (STEM) subjects urgently calls for innovations and improvements in learning and assessment process. As response to these concerns, the EU Horizon 2020-funded NEWTON project focuses on providing solutions that integrate innovative pedagogical learning approaches and technology enhanced learning materials. NEWTON Project's developed educational content is available through its platform - NEWTELP (NEWTON Technology Enhanced Learning Platform). Computer programming courses are considered to be very difficult. However, programming is a very useful skill and it is fundamental in computer science education. Various research papers, e.g. Alhazbi (2016), Horton & Craig (2015), Muntean et al. (2017) have reported their experiences of using technology-oriented teaching approaches including Flipped Classroom (FC), Game-based Learning (GBL) and Problem based Learning (PBL) when teaching STEM topics. These approaches actively engage students in their learning process as shown by Mason et al. (2013). Although these new technology-based teaching approaches have many advantages there are also many challenges related to developing materials for both online and in-class activities, game design and implementation. Educational games have been used a lot as a teaching tool in the past few years, especially due to the fact that students have become very familiarized with computer games in their everyday live. In paper by Anuradha at al. (2016) the effects of using a GBL approach in a programming course in a diploma programme were analysed and reported. Results show that students could easily relate gaming elements to difficult programming constructs, and they were highly engaged in learning. However the studies were limited and have not involved multiple international locations and many participants. This paper presents and discusses the results of a large-scale study of the effect of game-based learning in Programming courses. The study is part of the EU-funded H2020 project NEWTON and involves over 200 students from three European universities. The results show how by employing educational games in Programming courses, both learners' knowledge levels and their reported learning experience improves.

METHOD

During the Programming course, participants were exposed to a series of 3 (in Java courses) or 4 (in C courses) mini educational games developed by the NEWTON researchers from Dublin City University. Each game visualizes one of the fundamental concepts in the Programming course students struggle to grasp in general and provides students with an interactive and fun experience during the learning process. The *Variable* game visualizes the concepts of primitive data types, variable declaration and type casting using a warehouse

scenario. The *Function/method call* game illustrates the concepts of calling functions/methods and passing arguments in a firework scenario. The *Loop* game visualizes the concepts and operations of the "for loop" in an underwater scenario where the player controls a mermaid to carry out tasks of collecting gems for a certain number of times. The *Structure* game introduces and describes the concept of structure in C in a restaurant scenario. In this game, the player needs to design set menus, which represent structure templates in C. The first three games have two versions, for C and Java language courses, whereas the last game has a C version only. Example screenshots from the games are provided in the Figure 1.

The courses were deployed on 3 European universities in Ireland and Slovakia, respectively: Dublin City University (DCU), Slovak Technical University Faculty of Electrical Engineering (STU FEI) and Faculty of Informatics and Information Technologies (STU FIIT) and National College of Ireland (NCI). The aim of the study was to assess the benefits of the serious games for the programming course from two viewpoints: subjective usability and quality – assessed using questionnaire after each game, objective knowledge improvement – assessed via pre and post-test before and after each game. Before the start of each game, participants were asked to take a pre-test composed of 3 or 4 single choice questions related to the topics. Immediately after each game, participants took a post-test which contains 3 or 4 single choice questions as well. Participants were also given a game experience-related questionnaire after each serious game, which contains several questions about their objective feeling and game usability.

RESULTS

In this pilot, 244 students participated (133, 50, 39 and 22 students from DCU, STU FIIT, STU FEI and NCI, respectively). The results of objective knowledge improvement assessed via pre- and post-tests before and after each game are given in detail in Table 1. In generally it can be observed participant knowledge improvement, for most games in most location; however statistically significant improvements are noted for some of them only. In particular, good learning outcome is observed among DCU participants. For STU FIIT and FEI students, mixed learning outcome was noted, and these learning results are probably caused by a few factors including the fact that as the games were designed for beginners, they may be too easy for them or the fact that the game pace may be too slow. However the game related to the slightly more difficult topic - loops – had a significant success among all students, including those at STU.

DISCUSSION AND CONCLUSIONS

In this paper, we introduce a results from large-scale programming pilot with focus on serious games. During the pilot have been used different type of assessments such as questionnaires, pre-tests, post-tests to assess subjective usability and quality and objective knowledge improvement. Overall, the results show strong significance to knowledge improvement using serious games and college/university level.

In future work we will assess the variation of effectiveness and edutainment aspects of using a game-based learning approach for programming concepts across different students' demographic.

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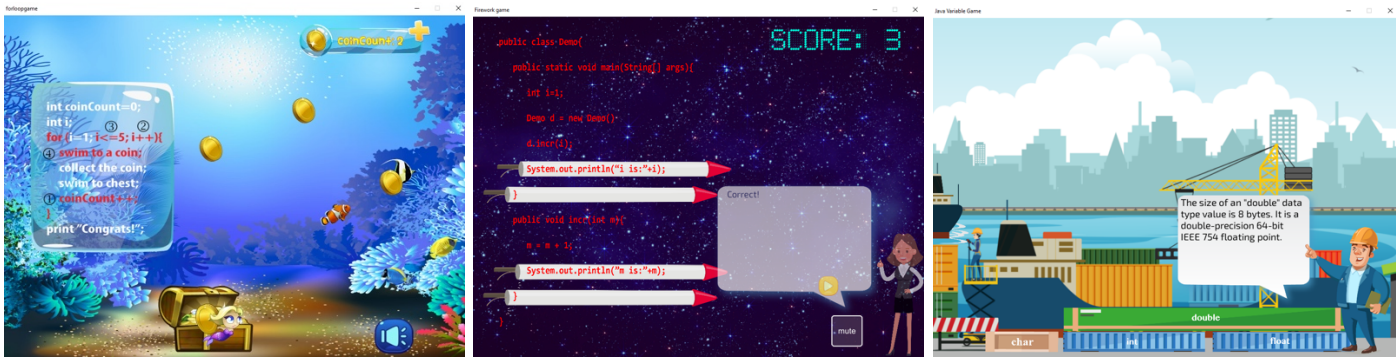

Figure 1. Example screenshots from used serious games (from left to right: the loop game, the method game, the variable game)

Table 1. Pre-test and post-test evaluation for the Programming course games. Significance tested using paired t-test at $\alpha = 0.05$.

	Location	pre-test score	Post-test score	t-value	p-value	Improved learning outcomes?	Statistically significant?
Variable Game	DCU	76.7	79.4	t(62)=0.75	0.45	Yes	No
	STU FIIT	86.3	79.5	t(38)=1.75	0.088	No	No
	STU FEI	76	79	t(32)=0.68	0.5	YES	No
	NCI	66.7	71.1	t(14)=0.62	0.54	Yes	No
For-loop Game	DCU	48.8	66.3	t(81)=4.4	0.000033	Yes	Yes
	STU FIIT	57.3	65.8	t(38)=1.76	0.086	Yes	No
	STU FEI	54,21	70,71	t(27)=2.86	0.008	Yes	Yes
	NCI	38	63.5	t(12)=2.54	0.026	Yes	Yes
Function/Method Game	DCU	62.5	76.7	t(95)=4.1	0.000078	Yes	Yes
	STU FIIT	61.5	64.1	t(38)=0.62	0.5385	Yes	No
	STU FEI	47,34	51,65	t(22)=0.46	0.65	Yes	No
	NCI	47.2	41.67	t(11)=0.45	0.65	No	No
Structure Game	DCU	58.6	76.1	t(89)=5	0.000003	Yes	Yes
Sorting Algorithm Game	DCU	55	52.5	t(39)=0.53	0.6	No	No