Game-based Learning in Computer Programming: Preliminary Results of a Large Scale Pilot Study Run at National College of Ireland

Eleni Makri, Neeraj Choudhary, Cristina Hava Muntean
National College of Ireland, School of Computing, Ireland

Abstract

This paper explores the students' knowledge achievement when the programming Loop game was used to teach students the loop statement principles. The Loop game was deployed as part of a large scale Programming pilot run at the National College of Ireland (NCI) in the first semester of a computing conversion course. 23 mature students participated in the case study that employed pre-and-post assessments while the Loop game was used as part of the lab session. Research findings indicate that students seemed to achieve improved knowledge performance in Java programming language coding of the loop concept after employing the game. The positive post-test assessment outcomes are discussed together with recommendations for further work in computer programming game-based learning.

1. Introduction

STEM-associated teachers and researchers have identified an elevated cognitive load for students while they are exposed to learn computer programming, leading to their lack of enthusiasm, enjoyment, positive orientation and commitment with both learning computer programming and STEM-related subjects alike [1]. These unfavourable student attitudes have led to the development of different technology enhanced pedagogies to assist the teaching and learning of computer programming discipline across different educational curricula worldwide. Game-based learning or else, educational computer or "serious games" [2 p. 1991] emerged during recent years and it seems to be an indicative example of such technology advanced approach with a strong learning potential [3]. Game-based learning assists students in experientially learning computer programming (i.e. involved way of learning), while enjoying the experience at the same time [4]. Despite the aforementioned favourable learning dynamics that educational computer games are claimed to have, a limited number of studies have been reported to evaluate whether games seem to support or advance computer programming learning [5].

In this context, this paper aims to present the preliminary results of a large scale pilot study run at the National College of Ireland (NCI) which explores the students' knowledge achievement when the programming *Loop* serious game was used to teach the *loop* statement principles during Semester 1 of the academic year 2018/2019. The pilot was deployed as part of the NEWTON EU Horizon 2020 research project[1]. NEWTON project has developed and evaluated diverse solutions based on innovative technologies for adaptive and personalised multimedia, multiple sensorial media delivery, Virtual and Augmented Reality (VR/AR) learning, Virtual Teaching and Learning Labs (Virtual Labs), Fabrication Labs (Fab Labs) and Gamification-based teaching and learning [6-11]. These solutions are used in conjunction with different pedagogical approaches including self-directed, game-based, flipped classroom, and problem-based learning methods [12-16]. The remainder of this paper is organised as follows. **Section 2** presents a brief summary review about game-based learning applications (educational games) for teaching and learning programming in higher education. **Section 3** presents the research methodology including the description of the programming *Loop* game and results' analysis. **Section 4** synopsizes the findings, their implications and concludes this paper with avenues for further research.

2. Literature review

The integration of computer games into different educational curricula has been indicated to advance students' learning, knowledge and skills' enrichment and commitment [17] [18]. Successful computer games are claimed to expose players or agents (i.e. students) to critical thinking and problem-solving skills whilst offering them immediate real-time feedback and prizes to motivate them to discover more solutions and good practice [2]. In addition, when a student interacts either individually or collectively with his or her peers in one computer or other computer agents (actors) in the game, is required to put his or her input and generate its' own learning.

[1]NEWTON project website, [Online] Available: http://newtonproject.eu

That input also combined with gameplay feedback per se, seems to assist the student in comprehending the game-associated concepts addressed each time [19].

Computer science higher education students tend to fall short of prior experience in employing programming concepts and practicing programming knowledge and skills leading to their lowered engagement in learning programming [20]. In helping them to learn and exercise the corresponding concepts more effectively, programming games have been designed, developed and disseminated predominantly over the last years. However, a limited number of studies are reported to evaluate whether these games seem to support or advance programming learning in effect [5]. As regards the learning effectiveness of programming games used in teaching programming modules at university at university level, there seem to be rather inconclusive findings as far as programming knowledge and skills, motivation and user experience features are concerned.

In summarizing a few indicative examples of them, are discussed next: Liu, Cheng and Huang [21] in their study assessing the learning experience of higher education programming students during their gameplay practice, indicated that those perceiving the game as motivational, developed their problem-solving knowledge and skills for programming learning. However, the programming students that did not indicate the game as engaging, did not seemed to develop their problem-solving competencies further after their programming gameplay experience. Mathrani, Shelly and Ponder-Sutton [22] in their study involving two groups of national diploma in computing students playing a programming game, indicated mixed findings in relation to the game's perceived learning effectiveness for programming teaching. Most students of the first group with no prior advanced programming knowledge but experienced in such gameplay before, they did perceive the game as fun and successful as a supportive tool for their programming game-based instruction. However, 20% of those participants did not indicate favourable responses regarding programming learning and computer games overall. As regards the second group of students who had already finished their basic programming course, 17% of them perceived the game as difficult to understand, although helpful in clarifying prior learned programming concepts. Overall, both groups of participants did indicate positive attitudes concerning the learning effectiveness of gameplay in understanding programming concepts. In retrospectively exploring the game's learning outcomes after four months, most of them reported that they had discussed with their lecturers and peers the programming concepts addressed in the game and employed particular elements of the game in their programming module project assignments.

Donald and McLeod [23] elaborate on a game developed as a tertiary education-commerce collaborative research effort for teaching preliminary programming knowledge and skills. 155 users of different demographic background played the game during an online community gameplay event session. 90% of the participants indicated they had fun with the game and reported favourable attitudes in terms of the game's usability design and immersion features. However, 60% of them reported that they did not learn more about programming objectives. The aforepresented indicative summary of gameplay studies for teaching programming in higher education, tends to reveal rather contradictory findings in relation to knowledge acquisition and learning experience aspects of programming games. In that respect, therefore, the exploration of knowledge and learning features as exercised in games used for teaching programming language coding concepts across diverse curricular courses within different social and cultural contexts, needs to be further addressed.

Following the rationale above, therefore, the current research work reported in this paper, aims to explore the effects of the programming *Loop* game on the knowledge performance of NCI's computing students when the game was used to teach them the *Loop* statement essentials.

3. Research methodology

3.1 Study design

The Programming pilot study adopted the pre-and-post-assessment approach (experimental design) when the programming Java *Loop* game was used as part of the Software Development module in National College of Ireland, Higher Diploma in Computing course as part of the lab session. 23 students of different demographic and academic background took part in the case study. The students were asked to answer pre-and-post knowledge tests corresponding to their pre-and-post playing learning experience with the programming *Loop* game that specifically addressed the learning and practice of Java programming language coding concepts through related questions designed for the needs of the present research. These were multiple choice (for each of the 3 questions) with their corresponding answers marked on a 0-3 scale pending on right or wrong answers provided during the pre-and-post knowledge test measurement.

3.2 Loop game

The *Loop* game presents the programming knowledge concept of *loop* through the completion of game activities (i.e. tasks and quiz) that correspond to

Figure 1 Loop Game

the compilation of coins as represented by the player who acts as a mermaid within an underwater storyline context (i.e. role-playing game) (Figure 1). It entails an only version which is applied to both Java and C Programming languages alike.

The game gas 3 levels that cover the fowling concepts through some tasks, as follows: a) basic *for* loop, where the coins need to be collected and stored (first level), b) *for* loop with *continue* statement, where some of the coins disappear once they are compiled by the mermaid (second level) and c) *for* loop with *break* statement, visualized by letting one of the coins becomes a jackpot coin (reward) once the mermaid collects them (third level), respectively. When the player (i.e. the mermaid) comes across a jackpot coin, then the corresponding activity is completed along with the level.

The activity of quiz which is taken after the students finish the tasks, requires them to answer a number of knowledge game-related questions. As the student (player) moves forward during the game, the code display on the screen alters in order to demonstrate the current routes that are being executed correspondingly, so that students are able to learn (practice) the order of the code execution inside a *for* loop.

3.3 Data analysis and results

Pre-and-post knowledge test scores were compared in terms of the average of the total marks and the percentage of the correct answers given by the NCI participants. The findings presented in *Table 1* and *Table 2* below, indicate that the average of the total marks for the 3 questions overall gained during post-knowledge test assessment was higher than the corresponding one in the pre-test (2.19 and 1.38, respectively). In addition, the percentage of the correct answers for all participants in questions 1 and 2 out of the 3 in the post-knowledge test was also higher than the corresponding ones in the pre-knowledge test assessment (90%, 57% and 14%, 38%, respectively). The percentage of the correct answers given by the students in all 3 questions overall during post-test assessment was higher than the corresponding ones in the pre-test measurement (75% and 46%, respectively). These results indicate that the NCI students seemed to achieve a better knowledge assessment performance in Java programming *loop* concept after employing the *Loop* game.

Table 1. NCI student marks for the pre-and-post knowledge test assessments

Programming *Loop* *Game Pre-test*	Programming *Loop* Game *Post-test*
Questions 1,2,3	
Average of total marks	
1.38	2.19

Table 2. Distribution of NCI's student correct answers for the pre-and-post knowledge test assessments

Programming *Loop* Game			
Pre-test		*Post-test*	
Question	correct (%)	Question	correct (%)
1	14%	1	90%
2	38%	2	57%
3	86%	3	76%
Average	46%	Average	75%

4. Discussion and conclusion

The results presented in this paper indicate that the *Loop* game seemed to help the NCI students to obtain a better knowledge achievement in Java programming language coding loop concept. Based on their lack of prior knowledge on the *loop* concept in Java, the *Loop* game was found to be useful as a particular exercise and learning tool for teaching and learning programming coding objectives.

The slightly more favourable percentage of correct answers provided by the participants for question 3 from the pre-test than the corresponding one in the post-test, may indicate the need for the *Loop* game to be additionally improved in terms of captivating the programming coding procedure learning.

However, the favourable post-test results outcome indicates that the game was perceived as a supportive application for computing students with less advanced knowledge and skills in programming language coding concepts. These findings tend to lend support to prior programming game-based learning ones obtained in higher education domain [21] [22].

Along this vein, it would be fruitful to explore additionally an appraisal of the *Loop* game in terms of programming knowledge acquisition features by

experienced users and (or) students in programming concepts along: a) its diverse game complexity levels (e.g. low, medium and high); b) following up on the impact of further metacognitive-and-community-associated attitudes and skills investigated in advanced intelligent systems settings [24], in respect also with individual traits (e.g. academic achievement, gender, educational background, etc.) and c) students motivation assessment and monitoring during the gameplay by making use of the MoGame mechanism [25][26]. These seem to be interesting questions and issues for further research in game-based learning for computer programming curricular objectives.

Acknowledgements

This work is supported by the European Union's Horizon 2020 Research and Innovation Programme via Grant Agreement no. 688503 for NEWTON Project (http://newtonproject.eu). The authors thank the NEWTON's Project participating partners, teachers and students that made this study possible.

References

[1] X. Chen, ″STEM Attrition among High-Performing College Students in the United States: Scope and Potential Causes″, *Journal of Technology and Science Education, 5, 1*, 2015, pp. 41-59

[2] C. Kazimoglu, M. Kiernan, L. Bacon, and L. Mackinnon, ″A serious game for developing computational thinking and learning introductory computer programming″, *Procedia-Social and Behavioral Sciences*, 47, 2012, pp. 1991-1999

[3] M. Olsson, and P. Mozelius, ″Learning to Program by Playing Learning Games″, Proceedings of the European Conference on Games Based Learning (ed.) Maja Pivec and Josef Gründler, Reading, UK, Academic Conferences and Publishing International Limited, 11, 498-506, 2017

[4] A.E. Chis, A.N. Moldovan, L. Murphy, P. Pathak, and C. Muntean Hava, ″Investigating Flipped Classroom and Problem-based Learning in a Programming Module for Computing Conversion Course″, *Educational Technology & Society, 21, 4*, 2018, pp. 232-247

[5] L. Sung, C. Hillyard, R.L. Angotti, M.W. Panitz, D.S. Goldstein, and J. Nordlinger, ″Game-Themed Programming Assignment Modules: A Pathway for Gradual Integration of Gaming Context into Existing Introductory Programming Courses″, *IEEE Education Society, 54, 3*, 2010, pp. 416-427

[6] I. Ghergulescu, T.Lynch, M. Bratu, A.N. Moldovan, C.H. Muntean and G.M. Muntean, "STEM Education with Atomic Structure Virtual Lab for Learners with Special Educational Needs", 10th International Conference on Education and New Learning Technologies (EDULEARN), Palma de Mallorca, Spain, pp. 8747-8752, 2018

[7] N. El Mawas, I. Ghergulescu, A.-N. Moldovan and C. H. Muntean, "Pedagogical based Learner Model Characteristics", Ireland International Conference on Education (IICE), Dublin, Ireland, April, 2018

[8] N. El Mawas, I. Tal, A. N. Moldovan, D. Bogusevschi, J. Andrews, G.-M. Muntean and C.H. Muntean, "Final Frontier Game: A Case Study on Learner Experience", Proceedings of the 10th International Conference on Computer Supported Education (CSEDU). Madeira, Portugal, pp. 122-129, 2018

[9] A.-N. Moldovan, I. Ghergulescu, C. H. Muntean, "VQAMap: A novel mechanism for mapping objective video quality metrics to subjective MOS scale", IEEE Transactions on Broadcasting, Vol. 62(3), pp. 610-627, 2016

[10] D. Bogusevschi, I. Tal, M. Bratu, B. Gornea, D. Caraman, I. Ghergulescu, C. H. Muntean, C. and G.-M. Muntean, "Water Cycle in Nature: Small-Scale STEM Education Pilot". In T. Bastiaens, J. Van Braak, M. Brown, L. Cantoni, M. Castro, R. Christensen, G. Davidson-Shivers, K. DePryck, M. Ebner, M. Fominykh, C. Fulford, S. Hatzipanagos, G. Knezek, K. Kreijns, G. Marks, E. Sointu, E. Korsgaard Sorensen, J. Viteli, J. Voogt, P. Weber, E. Weippl & O. Zawacki-Richter (Eds.), Proceedings of EdMedia: World Conference on Educational Media and Technology (pp. 1496-1505). Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE), 2018

[11] C. H. Muntean and J. Andrews, "Final Frontier: An Educational Game on Solar System Concepts Acquisition for Primary Schools", 17th IEEE International Conference on Advanced Learning Technologies (ICALT), Timisoara, Romania, pp. 335-337, 2017

[12] N. El Mawas, M. Bradford, J. Andrews, P. Pathak and C.H. Muntean, "A Case Study on 21st Century Skills Development Through a Computer Based Maths Game", In T. Bastiaens, J. Van Braak, M. Brown, L. Cantoni, M. Castro, R. Christensen, G. Davidson-Shivers, K. DePryck, M. Ebner, M. Fominykh, C. Fulford, S. Hatzipanagos, G. Knezek, K. Kreijns, G. Marks, E. Sointu, E. Korsgaard Sorensen, J. Viteli, J. Voogt, P. Weber, E. Weippl & O. Zawacki-Richter (Eds.), Proceedings of EdMedia: World Conference on Educational Media and Technology (pp. 1160-1169). Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE), 2018

[13] M. Bradford, C. H. Muntean and P. Pathak, "An Analysis of flip classroom pedagogy in first year undergraduate mathematics for computing", IEEE Frontiers in Education Conference (FIE), Madrid, Spain, pp.1-5, 2014

[14] C.H. Muntean, N. El Mawas, M. Bradford, and P. Pathak, "Investigating the impact of an immersive computer-based math game on the learning process of undergraduate students", Proceedings of the 48th Annual Frontiers in Education Conference (FIE) (pp. 1-7), San Jose, CA: IEEE, 2018

[15] T. Bi, F. Silva, G. Ghinea, and G. M. Muntean, "Improving Learning Experience by Employing DASH-based Mulsemedia Delivery", IEEE Games, Entertainment, Media Conference (GEM), Galway, Ireland, August, 2018

[16] D. Zhao, A. E. Chis, G.M. Muntean, and C.H. Muntean, "A Large-Scale Pilot Study on Game-based Learning and Blended Learning Methodologies in Undergraduate Programming Courses", 10th International Conference on Education and New Learning Technologies (EDULEARN), Palma de Mallorca, Spain, July, 2018

[17] T.M. Connolly, E.A. Boyle, E. MacArthur, T. Hainey and J.M. Boyle, ″A systematic literature review of empirical

evidence on computer games and serious games″, *Computers & Education, 59*, 2012, pp. 661-686

[18] I. Ghergulescu and C. H. Muntean, "Assessment of motivation in games based e-learning", in IADIS International Conference Cognition and Exploratory Learning in Digital Age (CELDA 2010), Timisoara, Romania, pp.71-78, 2010

[19] W.Y. Seng, and M.H.M. Yatim, ″Computer game as learning and teaching tool for object oriented programming in higher education institution″, *Procedia-Social and Behavioural Sciences, 123*, 2014, pp. 215-224

[20] P.H. Tan, C.Y Ting, and S.W. Ling, ″Learning difficulties in programming courses: undergraduates' perspective and perception″, International Conference on Computer Technology and Development (ICCTD), Kota Kinabalu, Vol. 1, pp. 42-46, IEEE, November, 2009

[21] C.C. Liu, Y.B. Cheng, and C.W. Huang, ″The effect of simulation games on the learning of computational problem solving″, *Computers & Education, 57, 3*, 2011, pp. 1907-1918

[22] A. Mathrani, C. Shelly, and A. Ponder-Sutton, ″PlayIT: Game Based Learning Approach for Teaching Programming Concepts″, *Educational Technology & Society, 19, 2*, 2016, pp. 5-17

[23] I. Donald, and K. MacLeod, ″Glitchspace: teaching programming through puzzles in cyberspace″. In: M. Pivec, J. Grundler, (eds.), Proceedings of the 11th European Conference on Games Based Learning, ECGBL, Reading: Academic Conferences and Publishing International Limited (pp. 148-154), 2017

[24] E. Makri, D. Spiliotopoulos, D. Koryzis, V. Svolopoulos, and P. Brinias, ″Exploring civic attitudes and skills within advanced intelligent systems context: The case of METALOGUE″. In first "Catch EyoU Conference: Young People as Active EU Citizens? Challenges and Visions on a Renewed Project for Europe" Book of Abstracts, 2nd-4th March, Amalia Hotel, Athens, Greece, 2017

[25] I. Ghergulescu and C.H. Muntean, "Motivation Monitoring and Assessment Extension for Input-Process-Outcome Game Model", International Journal of Game-Based Learning, Vol 4, 2014, pp. 15-35.

[26] I. Ghergulescu and C. H. Muntean, "MoGAME: Motivation based Game Level Adaptation Mechanism", in the 10th Annual Irish Learning Technology Association Conference (EdTech 2010) Athlone, Ireland, 2010