The Restaurant GAME: A NEWTON Project Serious Game for C Programming Course

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Abstract: *Restaurant Game* a 2D serious game focusing on the structure concept in C programming was designed and implemented as part of the European Horizon 2020 NEWTON Project. The game was deployed in a real-life pilot in the introductory software development module as part of first year undergraduate course at Dublin City University, Ireland. The game targeted the programming concept of structure and visualization of the concept major components through player interactions with the food and drinks in a restaurant scenario. The goal of the case study was to assess the impact of the game on students' learning outcomes and their subjective feelings towards game-based learning. 90 first year students from the Faculty of Engineering and Computing were involved in the study. The pre and post knowledge test results indicate there was a statistically significant knowledge gain after students' interaction with the game. The results of a post-game survey show how most of the students liked the overall design of the game and the game played a positive role in helping participants understand diverse knowledge aspects and improve their confidence in computer programming in general.

Introduction

In recent years, disengagement in science, technology, engineering and mathematics (STEM) subjects among the younger generations has been observed in most European countries, despite the fact that STEM professions and industries are important driving forces of economy growth (Joyce 2014). Such disengagement comes from many factors. For example, STEM subjects are very often perceived as being difficult, uninteresting and unrewarding by many students. Moreover, traditional ways of teaching, which are normally dominated by theoretical approaches, often fail to grasp the attention of students in such cognitively demanding subjects. To maintain European countries' competitiveness on the world stage in the future, innovation in STEM teaching is urgently needed to reverse this trend.

In order to alleviate the aforementioned crisis, many technology-enhanced education materials and innovative pedagogical approaches have been introduced into classrooms, such as serious games (El Mawas et al. 2018a), (El Mawas et al. 2018b) virtual reality (Bogusevschi et al. 2018), gamification (Sprint & Cook 2015), virtual labs (Lynch & Ghergulescu 2017) (Ghergulescu et al. 2018), flip-classroom (Bradford, Muntean, & Pathak 2014), problem based learning (Chis et al. 2018) fabrication labs (Togou et al. 2018). Serious games are games developed for non-entertaining purposes. Application of serious game in educational context have attracted attention from researchers from many countries as it has been proved that can increase learner motivation (Ghergulescu & Muntean, 2010). Serious games target at STEM education had been developed for various educational stages, e.g., for primary education as described in (Lester et al. 2014), (Beserra et al. 2017) and (Muntean & Andrews 2017) , for secondary education as described in (Khan, Ahmad, & Malik 2017), and for higher education, as listed in (Battistella & Wangenheim 2016), (Muntean et al. 2018). In particular, some prior work showed promising results of applying serious games in programming related courses. For example, the authors of (Galgouranas & Xinogalos 2018) presented a serious game which focuses on basic concepts of programming in general and object-oriented programming in particular. In (Miljanovic & Bradbury 2017), a serious game which concentrates on debugging techniques in different programming languages was studied.

This paper introduces and describes a 2D serious game called *NEWTON Restaurant Game* that focuses on the topic of *structure* in C programming. A case study that involved 90 first year undergraduate students from the Dublin City University (DCU)'s Common Entry to Engineering programme was conducted in order to assess whether the game improves learning outcomes and to evaluate students' subjective feelings while playing the game,. The case study was deployed during a lab session of the 12-week *Software Development for Engineers* module.

The research case study on the *NEWTON Restaurant Game* is part of the EU Horizon 2020-funded NEWTON Project (http://newtonproject.eu). The NEWTON Project aims at building a networked and versatile educational platform that provides unified seamless integration and fast dissemination of various technology-

enhanced learning contents and methods, including serious games, virtual labs, remote fabrication labs, adaptive multimedia enhanced learning experience (Bi et al. 2018) and multisensorial enhanced learning experience (Zou et al. 2017). To assess the impact of the project, several small- and large-scale pilots are being deployed across many European countries. The *NEWTON Restaurant Game* presented in this paper is part of the Programming large-scale pilot described in (Zhao et al. 2018).

The rest of the paper is structured as follows. The details of the *NEWTON Restaurant Game* is introduced in the next section. The following section describes the research methodology and analyzes the case study results. The last section concludes the paper.

The NEWTON Restaurant Game

The *NEWTON Restaurant Game* presented below is one of the four serious game applications that were designed, implemented and deployed at DCU as part of the NEWTON Programming large-scale education pilot. The 2D drag-and-drop game, developed with Unity engine, supports visualization of the programming concepts and conveys target knowledge during students' interaction with the game. The key computer programming concepts covered by the *NEWTON Restaurant Game* include: 1) defining a structure; 2) declaring structure variables; and 3) accessing structure members.

The knowledge to be covered by the game was discussed and decided during consultation meetings with relevant academics prior to the start of game design. The design and development of the game had been closely supervised by the DCU *Software Development for Engineers* module coordinator. Upon the completion of the game development, the game, including the knowledge explanatory text content inside the game, was carefully checked to guarantee its accuracy and correctness.

The overall scenario of the *NEWTON Restaurant Game* is a restaurant where the basic data types are interpreted as single food/drink types, such as pizza, dessert, drink, sushi, and structures are defined as "set menus" that include more than one types of food/drink. This game includes three levels that are presented next.

Level 1 – Creating Set Menus for the NEWTON Restaurant

At the beginning of this level, individual food/drink types, i.e., *sushi*, *pizza*, *dessert*, *drink* and *coffee*, available in the restaurant are introduced to the player. These are equivalent to basic data types in C. Then, the player is asked to create a sushi set menu (equivalent to defining a structure *sushiSet* in C) and a pizza set menu

Figure 1 NEWTON Restaurant Game - Level 1

(equivalent to defining a structure *pizzaSet* in C) (see Fig. 1). The sushi set menu (*sushiSet* structure) is a collection composed of *sushi*, *dessert*, *drink*, while the pizza set menu (*pizzaSet* structure) is a collection including *pizza*, *dessert* and *coffee.* The creation of set menus is done by the player dragging and dropping the food icons into the corresponding menu pages. In every step of the level, the programming knowledge targeted is explained in details by a chef non-player character introduced at the bottom right corner of the screen. Moreover, the actual code (except from replacing C data types by food data types) is shown on the blackboard at the top right corner. The code changes with the progress of the game to reflect the construction process of the structures.

The main knowledge aspects covered in this level include the definition of structure, general syntax for a *struct* declaration (i.e. with tag name) and using *typedef* keyword to give the structure a type name.

Level 2 – Order a Sushi Set

In the second level, the player will order his/her own sushi set, which is equivalent to declaring a structure variable (see Fig. 2). The player makes his/her choice of each food/drink in the set menu by dragging and dropping the food/drink to the sushi mat. In the context of programming, this step requires accessing the members of the structure variable and assigning values to them. Similar to the chef in the first level, the sushi girl non-payer introduced at the bottom right corner of the screen explains details of the programming knowledge targeted, as well as the actual code lines, in every step of the level. Upon finishing of all actions, the sushi girl will go over the key points of declaring a structure and declare a structure variable. This reinforces the knowledge introduced. The main knowledge aspects covered in this level are syntax for declaring a structure variable (using structure tag name), accessing members using member access operator and declaring a structure variable (using structure's type name).

Figure 2 NEWTON Restaurant Game - Level 2

Level 3 – Order a Pizza Set

In the third level, the player will create his/her own pizza set and choose his/her food/coffee (see Fig. 3). The game flow in this level is similar to that in the second level. The purpose of this level is to reinforce the player's understanding of the knowledge aspects already introduced, and most importantly, the difference between declaring a structure and a declaring a variable of a structure, as these are the concepts the academics have noted the students have struggled the most with.

Figure 3 NEWTON Restaurant Game - Level 3

Case Study Results

As mentioned earlier in this paper, the primary goals of the *NEWTON Restaurant Game* are to increase students' interest in the Programming course, to improve their confidence in programming and to maintain or potentially improve their learning outcomes.

In order to evaluate whether the *NEWTON Restaurant Game* has met the goals, a case study was conducted among 90 participants who were all first-year undergraduate students in the Faculty of Engineering and Computing in Dublin City University (DCU), Ireland. In terms of gender composition, 77% of the participants were male and 23% were female (i.e. typical gender distribution in engineering). According to a demographic survey conducted prior to the Programming pilot, the majority of them (77%) play games and about half of them had serious game experience before this case study. The game was deployed during a lab session in the *Software Development for Engineers* module at DCU during the second semester of the 2017/2018 academic year. The related topics were taught by the lecturer in a classic manner during lectures before the scheduled lab session. The case study includes four steps and were all done through the NEWTELP platform. This platform is an innovative learning management system developed part of the NEWTON project. First, a pre-test that included 4 single choice questions on the target knowledge points was provided to the participants to assess their knowledge level before the exposure to the game. Then, the participants downloaded the *NEWTON Restaurant Game* from the NEWTELP Platform and played it. Upon finishing the game, the participants took a post-test which also included 4 single choice questions. At last, the participants were asked to complete a survey about their subjective feelings of the game. The survey questions are all single choice questions with 5-level Likert scale answer options: *strongly disagree*, *disagree*, *neutral*, *agree*, and *strongly agree*.

The pre-test and post-test were designed in such a way that each question covers the same topic (i.e., question 1 in pre-test and post-test are about the same knowledge point, etc.) and questions in post-test is either at the same difficulty level or slightly more difficult than those in pre-test for fair comparison.

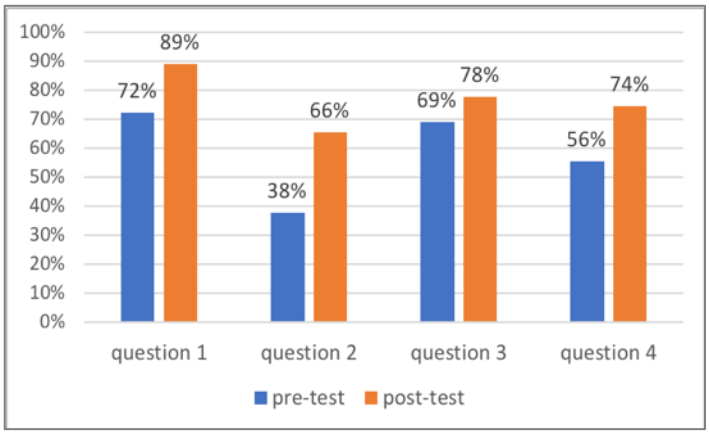

Figure 4 Percentage of students answered each question correctly in pre-test and post-test

Fig. 4 shows a comparison between the pre-test and post –test questions. Once can noticed that, there is an increase in the percentage of students that selected the correct answers in the post-test. Specifically, 72% of the students answered question 1 correctly in the pre-test, whereas 89% of the participants answered question 1 in post-test correctly (an increase of 17%); 38% of the students answered question 2 correctly in the pre-test whereas the percentage of students who answered question 2 correctly in post-test reached 66% (almost doubled); question 3 has also seen an increased percentage of correct answers from 69% in the pre-test to 78% in the post-test; 56% students answered question 4 correctly in the pre-test, whereas nearly three quarters of them answered question 4 correctly in the post-test.

On average each student answered 2.3 questions out of the 4 correctly in the pre-test, whereas on average each student answered 3 questions out of the 4 correctly in the post-test, as illustrated by Fig. 5. The comparative improved performance of students in the post-test is demonstrated to be statistically significant by a t-test with $\alpha = 0.05$ ($t(89)=5$, $p=0.000003$). Moreover, 22 students (24%) obtained full marks in the pre-test, whereas 35 students (38%) obtained full marks in the post-test (see Fig. 6).

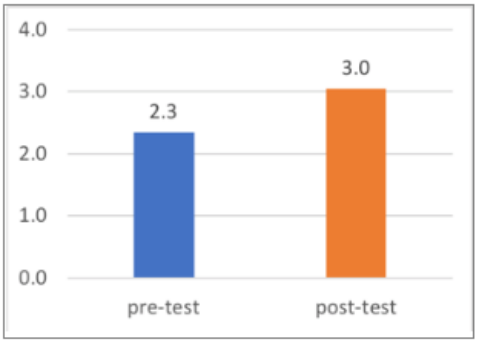

Figure 5 Average number of questions answered correctly by each student

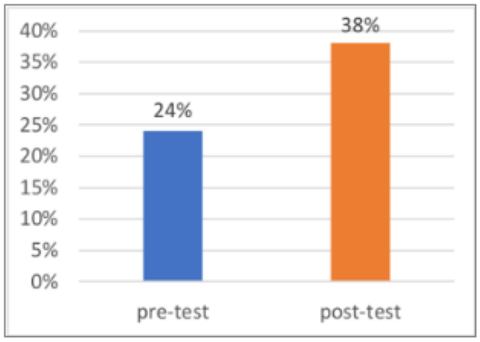

Figure 6 Percentage of students who achieved full marks

The post-game survey questions mainly focused on the usability of the game and participants' subjective feelings towards the game. The results of the survey imply the design of the *NEWTON Restaurant Game* gained acceptance among most participants. Fig. 7 shows that over 70% of the participants strongly agreed or agreed that the game tasks and levels were properly designed, and they understood all the different parts of the game.

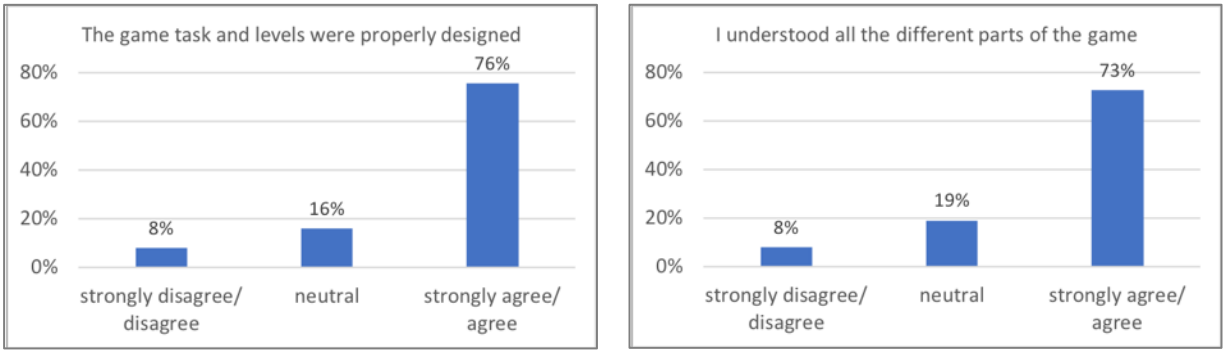

Figure 7 Results of usability-related questions

As indicated in Fig. 8, around 65% of the participants gave positive answers when asked if the game targeted their knowledge gaps and 64% did the same when asked if the game helped them understand the programming concepts. For both questions, only less than 10% of participants gave negative feedback. This shows the vast majority of participants subjectively felt they learnt the targeted knowledge while playing the game.

More than half of the participants (56%) strongly agreed or agreed that the game could help them achieve better results in the programming course, whereas only 15% of them disagreed with this statement (Fig. 9). This indicates

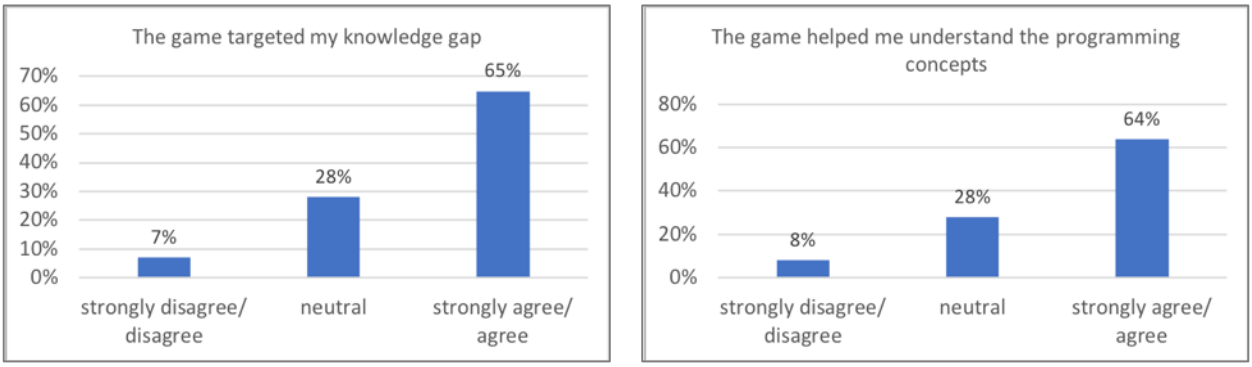

Figure 8 Survey results of knowledge acquisition related questions

that the *NEWTON Restaurant Game* played a positive role in improving students' confidence in programming, which, as we discussed earlier, is crucial in maintaining students' engagement in third level STEM education. Moreover, more than 60% of participants gave positive feedback to the question "*This game is a good complement to textbooks and lecture slides on this topic*", while only 11% of them gave negative feedback.

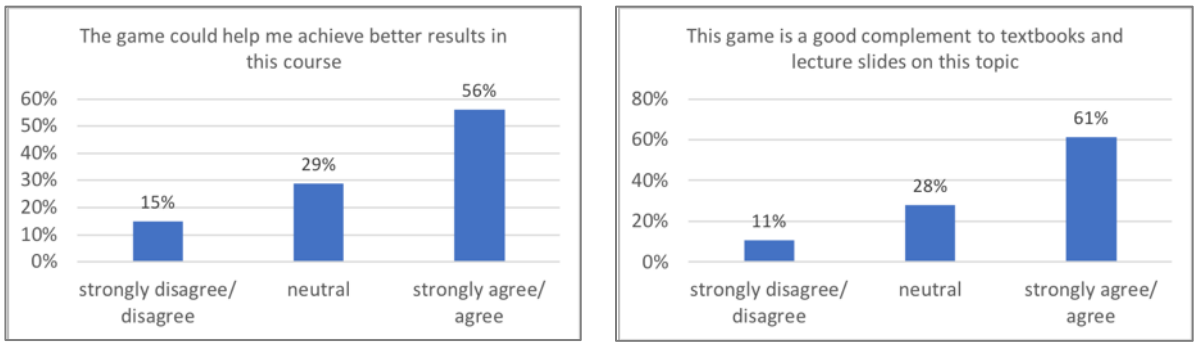

Figure 9 Survey results of affective state related questions

Conclusion

This paper presented the *NEWTON Restaurant Game*, a 2D serious game that focuses on the *structure* concept in C programming. In this game, basic data types in C are represented by food and drinks, whereas structures in C are represented by set menus in a restaurant scenario. The game visualizes key concepts such as declaring a structure, declaring a variable of a structure, and accessing members of a structure, through player's interactions with the food/drinks in the restaurant. A case study that involved 90 first year students from the

Faculty of Engineering and Computing was conducted in Dublin City University, Ireland during a lab session of an entry-level *Software Development for Engineers* module. According to the results of the pre and post knowledge tests conducted before and after participants' exposure to the game, there was a statistically significant improvement in learning outcomes, i.e., the average number of questions answered correctly by each student increased from 2.3 (out of 4) in pre-test to 3 (out of 4) in post-test. The rate of correct answer for each question and the percentage of students who achieved full marks also improved after the interaction with the game. A post-game survey revealed that the overall design, from both educational context and aesthetics perspective, and the usability of the game obtained general acceptance among participants. Moreover, over 60% of the participants claimed the game helped them understand better the programming concepts and more than half of the participants believed the game could help them achieve better results in the course.

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