THE NEWTON PROJECT WAREHOUSE GAME: A VARIABLE AND DATA TYPE SERIOUS GAME FOR C PROGRAMMING COURSES

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Abstract

This paper presents a serious game, the Warehouse game, which is designed and developed as part of the NEWTON project and deployed at Dublin City University (DCU), Ireland, in the EM108 Software Development for Engineers course, taught to all first year DCU Engineering students. This game has three levels, targeting C data types, variable declaration and type casting concepts. In level one, students are introduced to a warehouse scenario where the basic data types in C are taught in interactive manner. In level two, the computer memory is visualized as shelf spaces in the warehouse and data values are interpreted as goods with different sizes. The students are asked to conduct a set of tasks to complete the process of declaring variables and assigning values. In level three, students are guided to carry out tasks that declare variables and assign values of unmatched data types to them, learning the concept of type casting. To evaluate the impacts of the game, a comprehensive case study was conducted involving 93 undergraduate students. Pre-test and post-test that contain several single choice questions targeting the related programming concepts were given to students before and after the game to assess the game's influence on the learning outcomes. The results show students' knowledge level improved after playing the game. A game experience survey was also given to the students following the game to measure their satisfaction levels. The survey results indicate that most of the participants liked the design of the game and the game helped to stimulate their interests and improve their confidence in the subject.

Keywords: serious game, programming course, STEM subjects

1 INTRODUCTION

In recent years, most European countries have witnessed declines in terms of engagement in science, technology, engineering and mathematics (STEM) subjects among their younger generations. The potential shortage of scientists in the future is endangering European countries' competitiveness in related areas. The perception among students that STEM subjects are difficult to learn is one of the major underlying issues behind this crisis. This is justified by the fact that there are very high failing rates in many STEM subjects, including programming related courses. Despite the fact that most of the third-level students who choose STEM majors make this decision out of enthusiasm and personal interest in STEM subjects, high failing rates decrease students' motivation and increase their course drop rates.

To address the aforementioned crisis, many researchers have proposed to bring innovative technology enhanced learning (TEL) methods to traditional classrooms to stimulate students' engagement and interests as well as improve their learning outcomes. Serious games, in particular educational serious games, which are games developed for educational purpose rather than pure entertainment, are among the most popular ones. In recent years, serious games have been widely applied to various education subjects and targeted different education levels. Research work in this area revealed positive impacts and outcomes of games in educational context [1] [2]. Application of serious games in computer science subjects have been carried out by many researchers [3]. For example, Miljanovic and Bradbury [4] presented a serious game developed for programming novices, targeting at a series of programming concepts.

This paper presents a research study on the impacts and outcomes of a 2D serious game, the NEWTON Project Warehouse game, which targets at helping students to understand the concepts of data types, variable declaration and type casting in C programming. The effectiveness of this game was assessed through a case study carried out among 93 first year undergraduate Engineering students at Dublin City University, Ireland. The game was played during the second lab session in the 12-week *Software Development for Engineers* module.

The research case study presented in this paper is part of the EU Horizon 2020-funded NEWTON Project (http://newtonproject.eu) [5]. The NEWTON project has built a networked educational platform that supports seamless integration and dissemination of various technology-enhanced learning content and methods, including augmented reality, virtual reality, virtual labs [6], serious games [7] [8], adaptive

multimedia [9] [10] and multisensorial content delivery [11], remote fabrication labs [12], and innovative teaching and learning approaches [13] [14]. Multiple pilots are deployed in different educational institutions in several European countries to validate the outcomes and effectiveness of the NEWTON project. The NEWTON Project Warehouses game introduced in this paper is part of a large-scale pilot deployed in three universities in Ireland and Slovakia.
The rest of the paper is structured as follows. Section II presents the details of the NEWTON Project Warehouse game. Section III describes the research methodology and analyzes the case study results. Section IV concludes the paper.

2 THE NEWTON PROJECT WAREHOUSE GAME

In this Warehouse serious game, students learn the concepts of variable declaration and truncation of variables. The educational content conveyed in this game includes:
1) different data types require different amount of memory space;
2) when a variable is declared, the required amount of memory space is allocated;
3) assigning a value to a variable means storing the value in the memory space allocated to the variable; and
4) when assigning a value of a different type to a variable, type casting may happen.
The scenario of the game includes a warehouse where the computer memory is visualized as shelf spaces in the warehouse and variable values are visualized as boxes with different sizes. The game has 3 levels or activities.
Level 1 – introduction to basic data types. There are various data types in C, each of them has certain size. At the beginning of the game, the player enters the NEWTON project cargo. Here, different data types and their sizes are demonstrated. Boxes with different sizes that represent different data types are dropped one by one, while their definitions and sizes are introduced.

Figure 1 NEWTON Project Warehouse Game - Level 1

Level 2 – declaring variables. In this level, the player enters a warehouse, which represents the memory of computer. Inside the warehouse, each byte in the memory is represented by a square space on the shelf. The number tag under each shelf space is its address in memory. The player follows the instruction given by the game and carries out the actions of declaring and initializing a “char” type variable, an “int” type variable, and a “double” type variable, which have sizes of 1 byte, 4 bytes and 8 bytes, respectively. For each variable, the player needs first to allocate the memory space required by clicking on the empty shelf space (e.g., the player needs to single click 4 consecutive shelf spaces to allocate enough memory for an integer variable). After each click, an “occupied” stamp shows up on the space which indicates the space has been allocated to the variable. Then, the player initialises the variable by dragging one of the corresponding boxes to the occupied shelf space.

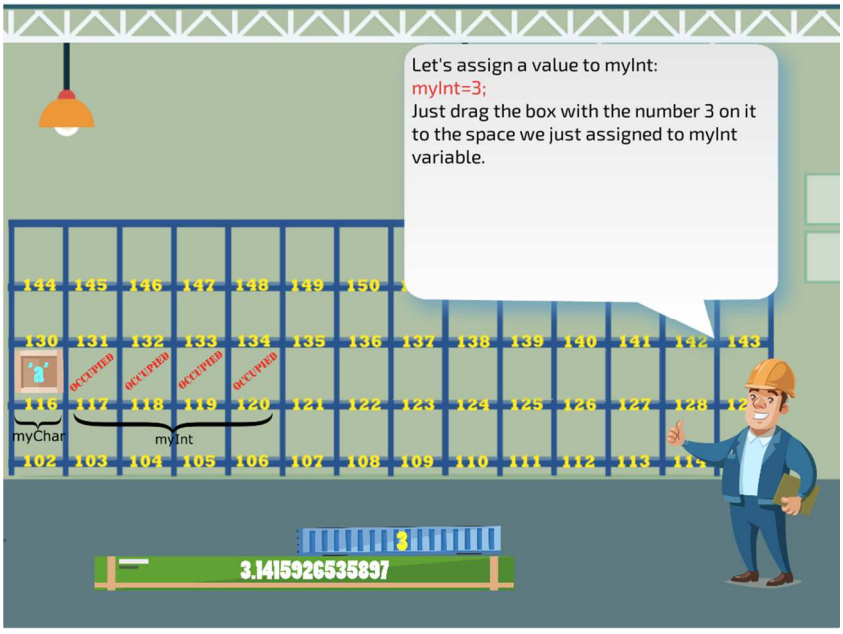

Figure 2 NEWTON Project Warehouse Game - Level 2

Level 3 – the pitfall: type casting. In this level, the player learns what happens when they assign values of mismatching data types to variables. First, the player declares an "integer" type variable and allocates a 4-byte space for it. However, when assigning a value to this variable, the player is asked to try to drag a "double" type value box, which has a length of 8-byte, into the 4-byte space allocated for the integer variable. Upon this action, the box is truncated to half and the double precision number shown on it is truncated too, so that only the integer part is kept. Then, the player declares a "double" type variable and allocates an 8-byte space for it. Instead of assigning a double type value to this variable, the player is asked to drag an integer value to the spaces allocated to the double variable. The size of the integer variable box is doubled and a decimal point and zeros are padded to the end of the integer value. This turns the integer value into a double value.

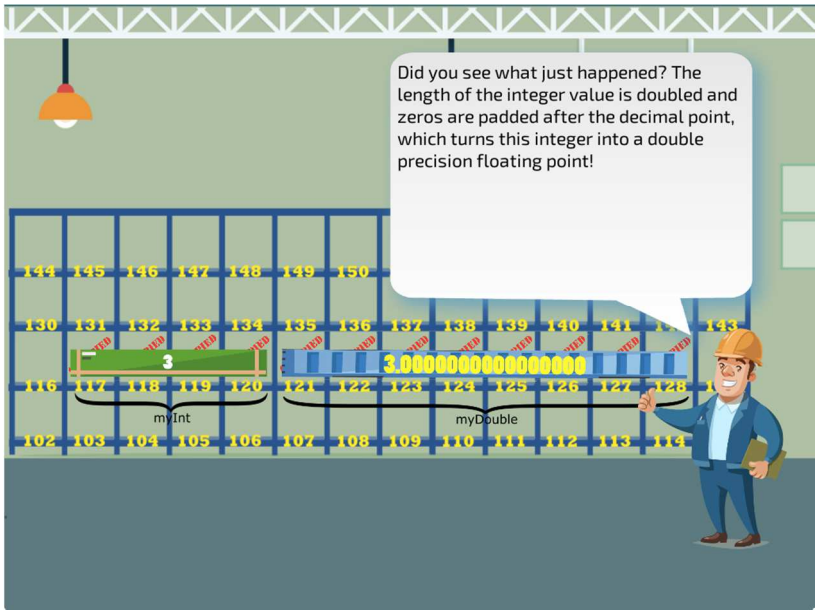

Figure 3 NEWTON Project Warehouse Game – Level 3

3 CASE STUDY RESULTS

In this case study, we investigated both students' subjective feedback on the game and their learning outcomes through playing the game. This game was included as part of a lab session in the EM108

Software Development for Engineers module in Dublin City University, Ireland in the Spring semester in 2017/2018 academic year. This module involves all first year undergraduate Engineering students from the Faculty of Engineering and Computing. According to the results of a demographic survey that 93 students participated in at the beginning of the semester, 77% of them are male and 23% are female. The majority (86%) of them claimed they like/love learning science and 75% of them got good marks in STEM subjects sometimes or always before. 77% of them play games and 47% believe they have above average gaming skills. Around 50% of them had played serious games before the case study.

The methodology of the case study is as follows. During the lecture session, which was one day before the lab session, students learned related topics in class. During the lab session, students logged into the NEWTON project platform NEWTELP (http://newtelp.eu) and took part in a pre-test that includes 3 single choice questions that assessed their knowledge level of the topics covered by the game before they were exposed to the game. Then, they downloaded the game from the platform and played the game on the computers. After they finished the game, they took a post-test that also includes 3 single choice questions to assess their knowledge level after exposure to the game. The students were also asked to complete a survey that included 12 single choice questions, each with 5 Likert Scale answer options: *strongly disagree*, *disagree*, *neutral*, *agree*, and *strongly agree*.

The results of the pre- and post-tests are shown in Table 1 and Table 2, respectively. The difficulty levels of each question are also indicated. Question 1 in the pre-test and Question 1 in the post-test targeted the same topic and both have a difficulty level of “easy”. The correct rate increased from 93% to 98% from the pre-test to post-test. Question 3 in the pre-test and Question 2 in the post-test targeted the same topic and both have a difficulty level of “hard”. The correct rate increased from 60% before the game to 72% after the game. In the post-test, more than half of the students answered correctly the third question, which is of “very-hard” difficulty level. Overall, the test results have shown that more students could answer questions of the same difficulty levels after they played the game, which indicated they were able to learn better targeted programming knowledge through playing the Warehouse serious game.

Table 1 Variable Declaration Game pre-test results

Question No.	Difficulty Level	Correct Rate
1	Easy	93%
2	Medium	71%
3	Hard	60%

Table 2 Variable Declaration game post-test results

Question No.	Difficulty Level	Correct Rate
1	Easy	98%
2	Hard	72%
3	Very hard	51%

Students’ subjective experience of the serious game was assessed through a survey after the game. The results of the survey are summarized in the stacked bar chart in Figure 4. Results show that 73% of students (56% agreed and 17% strongly agreed) thought the game was a good complement to textbooks, and more than half of them claimed to be more interested in the course after playing the game. At the same time 78% of students agreed (63% agreed and 15% strongly agreed) the game helped them to understand the programming concepts and 65% of the students (49% agreed and 16% strongly agreed) believed the game could help them achieve better results in the course. Regarding the quality of the game, 77% of students agreed (64% agreed and 13% strongly agreed) that the game tasks and levels are well designed, 84% thought the User Interface (UI) design is pleasant and 66% of

them believed the game targeted their knowledge gap. Furthermore, 58% of students denied they would prefer to learn without serious games. It can be concluded from the results that the Warehouse game is in general well designed and appreciated by most students. The game also fulfilled its purpose of motivating students and improved their learning outcomes.

4 CONCLUSION

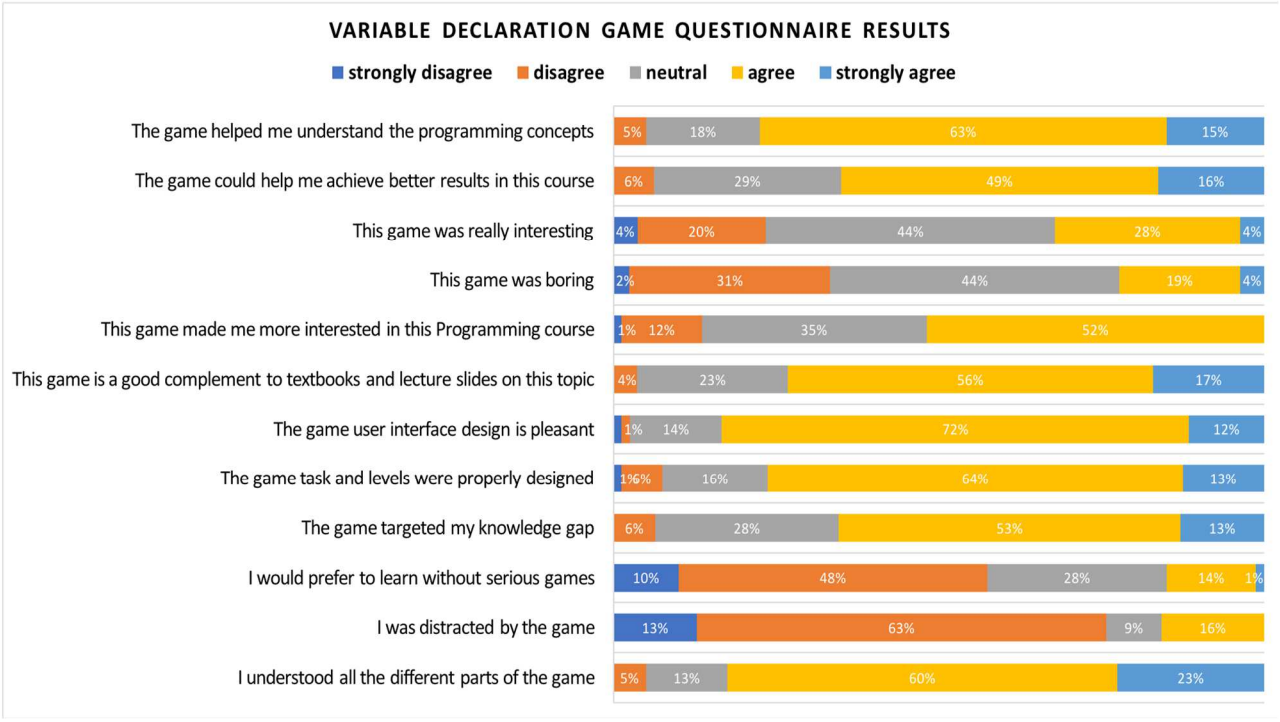

Figure 4 Stacked bar chart of game experience survey results

This paper introduced the *NEWTON Project Warehouse Game* – a 2D serious game about data types and variable declaration for university level C programming modules. This game covers the knowledge of basic data types, variable declaration and type casting in C programming. This research case study was conducted in a first-year undergraduate software development module in the Faculty of Engineering and Computing at Dublin City University, Ireland. The students' subjective experience was investigated by a game experience survey and their learning outcomes via pre-test and post-test. Result analysis of the survey indicate that the *NEWTON Project Warehouse Game* was liked by most students from both educational content perspective and aesthetics perspective. The game experience was able to stimulate students' interest and make students more confident in learning in this module. From the results of pre-test and post-test, it can also be concluded that the game produced good learning achievements as significantly increased number of students were able to answer questions of the same difficulty levels correctly after the game.

ACKNOWLEDGEMENTS

This research is supported by the NEWTON project (http://www.newtonproject.eu/) funded under the European Union's Horizon 2020 Research and Innovation programme, Grant Agreement no. 688503.

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