Demonstrating data carving concepts using jigsaw puzzles: a preliminary study

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Abstract: According to the non-continuation rates for the 2015-2016 intake published by the Higher Education Statistics Agency, almost 11 % of computer science students withdrew from universities after their first year, being the highest amongst all subject areas. The reasons for this are varied; including students' age, health issues, the amount of study load, and financial difficulties. However, a lack of motivation has been cited as being a significant factor. Within the School of Computing at University of Portsmouth, a number of methods are being investigated to enhance the student's learning and teaching experience in order to decrease withdrawal rates. For our BSc (Hons) Cyber Security and Forensic Computing course, students need to master various topics. One of these has been conceptually difficult to comprehend due to the high level of abstract understanding required; data carving. Within the digital forensic domain, the purpose of data carving is to reassemble files from fragments in the absence of file system metadata; those carved files could contain valuable artefacts that can be used to prove/disprove alleged offences within a forensic investigation. Although the idea of data carving seems to be simple, it does require students to have a deep understanding of how data is stored on a storage device and various file identifiers. Based upon the authors' experience, these are difficult for students to grasp without an adequate visualisation. In order to demonstrate the data carving concept more clearly and improve the student engagement at the same time, a jigsaw puzzle game is used to demonstrate data carving concepts (i.e. reassembling pieces of an object together). During the 2017-2018 academic year, two groups of Cyber Security and Forensic Computing students were recruited to pilot the proposed idea. In total 32 students provided their feedback via a questionnaire after the jigsaw activity. 84% of the students thought that the puzzle activity helped them to understand the data carving concept; also more than four-fifths of the students claimed that they enjoyed the puzzle game.

Key words: computing students, withdrawal rate, student engagement, game based learning, data carving, jigsaw puzzle.

1. Introduction

Within the UK higher education sector, the number of first year student enrolments has grown steadily over the period from 2012/13 to 2016/17, with 548,415 student entrants for the year 2016/17 alone (Higher Education Statistics Agency (HESA), 2018a). Despite their high level of commitment (including paying £9,000 tuition fees per year), not all first year students have progressed into the second year of their study; more worryingly, the proportion of first years dropping out from university has risen continuously over the last few years, notably 5.7%, 6.0%, 6.2%, and 6.4% for academic years 2012/13, 2013/14, 2014/15, and 2015/16 respectively (HESA, 2018b; HESA, undated). For those who dropped out from the higher education after their first year study, their degree programs cover all subjects. However, according to the withdrawal rates for the 2015-2016 intake published by the HESA, almost 11% of computer science students withdrew from universities after their first year, being the highest amongst all subject areas (HESA, 2018b). With the aim to investigate the reason why students may withdraw from their studies, several research projects were conducted; their results suggest that the reasons for this are varied, such as students' age, health issues, the amount of study load, and financial difficulties (Altin and Rantsus, 2015; Xenosa *et al.*, 2002). However, a lack of motivation has been cited as being a signification factor (Kinnunen and Malmi, 2006; Paura and Arhipova, 2014).

At the School of Computing in University of Portsmouth, a number of methods are being carried out to enhance the student's learning and teaching experience in order to decrease withdrawal rates, such as providing personal tutoring support and adopting various technologies for teaching. For our BSc (Hons) Cyber Security and Forensic Computing course, students need to master various topics, including digital forensic investigation principles, computer architecture, operating systems and data carving. Within the digital forensic domain, the purpose of data carving is to reassemble files from fragments in the absence of file system metadata; those carved files could contain valuable artefacts that can be used to prove/disprove alleged offences within a forensic investigation. Although the idea of data carving seems to be straightforward, it does require students to have a deep understanding of how data is stored on a storage device and various file identifiers; these could be difficult for students to grasp without an adequate visualisation. To this end, the paper demonstrates a preliminary study that uses a jigsaw puzzles activity to demonstrate data carving concepts and enhance student engagement and learning.

The remainder of paper is structured as follows: Section 2 reviews existing studies that are proposed and used for enhancing student engagement and learning. Section 3 describes the proposed method. Section 4 demonstrates students' feedback upon the proposed method, along with a detailed discussion. Section 5 concludes the paper and highlights future research directions.

2. Literature Review

Due to its importance to teaching and learning (e.g. students learn more when they are engaged), student engagement is a well-established domain for educational research (Gettinger and Ball, 2007). Many aspects of student engagement have been studied, including types of engagement and strategies that can be used for enhancing student engagement.

Based upon prior studies, Fredricks *et al.* (2004) offer a comprehensive review that summarises the three facets of engagement, naming behavioural engagement, emotional engagement and cognitive engagement, along with what they are, their various forms, pros and cons in great detail. Also, Fredricks *et al.* (2004) and Fredricks and McColskey (2012) discuss a wide range of techniques that were developed for measuring these three facets. Whilst the justification on why positive student engagement is required is being continuously researched, various strategies are also being designed, developed and tested. Amongst those strategies, game-based learning is about the use of games to enhance students' learning experience (Plass *et al.*, 2015). Jovanovic and Chiong (2012) suggest that games can help learners to improve various important skills, including problem-solving, communication and non-linear thinking patterns.

Within the computer science domain, a number studies were conducted focusing upon the use of games to help students to learn programming, such as Muratet *et al.* (2009), Kazimoglu et al. (2012) and Schafer *et al.* (2013). In additional, students can learn programming via a range of games, including CodinGame, Screeps and Vim Adventures (Mybridge, undated). To date, little research has been conducted on how to utilise game

based learning to help cyber security and forensic computing students to comprehend various related subjects. As a result, this paper proposes the idea of utilising a well-known game to demonstrate the data carving concept and enhance student learning.

3. Methodology

Once the idea of using a game-based learning method for teaching digital forensic subjects is formed, an activity that utilises jigsaw puzzles is designed and implemented to facilitate the data carving teaching session in three phases. During the preparation phase, 12 individual jigsaw puzzle sets are selected with each containing different number of pieces (ranging from 9 to 36). Then, a number of pieces are purposely removed from several random selected jigsaw puzzle sets; this is to simulate various data carving scenarios, including files that can be fully carved and partially carved (as demonstrated in Figure 1). Finally, the remaining pieces from all 12 sets are mixed together as if they were file segments that are stored on a data storage device. At the implementation stage, grouped students are tasked to carry out two activities: 1) retrieve all pieces of one puzzle from the collection; this can be achieved based upon the colour coding of the backside of each puzzle; and 2) reassemble all available pieces to complete the puzzle. After the puzzle activity, students are asked to provide their feedback by completing a survey which only contains two 5-point Likert Scale questions and one open ended question. The first Likert Scale questions is used to explore whether the jigsaw puzzle activity could help the student to understand the data carving concept better; the second is used to check whether the student enjoyed the activity. The open ended question is used to obtain any comments that the student may have regarding the activity.

a b c d

Figure 1: Examples of data carving scenarios (a: full carved; b, c and d: partially carved)

This activity was introduced to students during the 2017/18 academic year. In total 45 students participated the activity, while 32 of them completed the questionnaire either via a paper based survey or through an online based quiz, both of which had the exactly same set of questions. Details of the students' feedback on the proposed activity are presented in the next section.

4. Results and Discussions

As illustrated in Figure 2, 45% of the participants (out of 32) strongly agreed that the puzzle activity helped them to understand the data carving concept; while 39% somewhat agreed. In comparison, only two of the students thought they did not benefit from the activity; and none of the students were strongly opposed the idea.

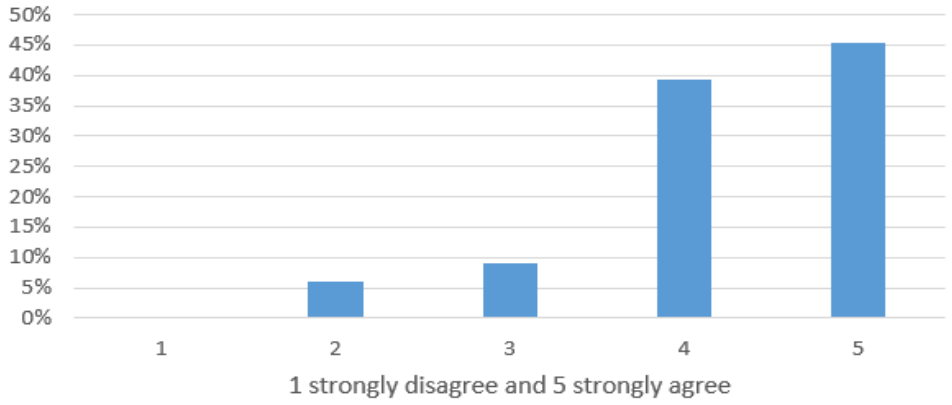

Figure 2: Participants' answers on the usefulness of the puzzle activity on learning the data carving concept

When asked whether they enjoyed the activity, 42% of the participants strongly indicated that they did enjoy the activity; also the same proportion (i.e. 42%) of participants found the activity somewhat enjoyable. In contrast, only 3% of the students (i.e. 1 in 32) claimed that they did not find the activity somewhat enjoyable. None of the participants reported that they did not completely enjoy the activity.

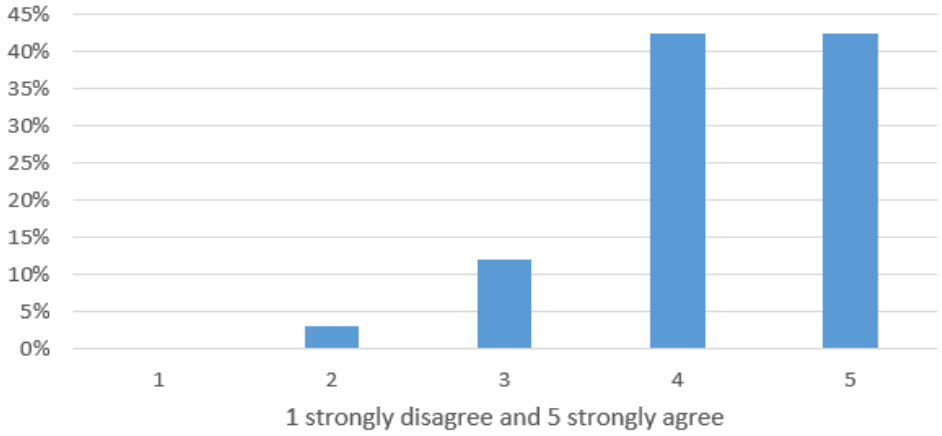

Figure 3: Participants' responses on whether they enjoyed the activity

Regarding the response to the open ended question, similar patterns are found as those being observed from the two Likert Scale questions. Students found the proposed activity helped them to learn the topic as one claimed that "It was good as it made me more aware of the parts that could be missing from a file and that data carving is basically piecing together files bit by bit"; also another commented that this was a "Good and simple exercise that fully explains the data carving concept". Students also confirmed that the proposed activity was enjoyable, as one stated that "it was fun :D"; and more importantly, students remarked that the proposed activity is "Enjoyable; different ways of engaging are always welcome".

As demonstrated by the results, the proposed method did assist the students in comprehending the data carving concept that is an abstract digital forensic subject via the visualisation aid of the jigsaw puzzle. Also, the activity is relatively easy to set up. Students enjoyed the proposed learning activity; this is also confirmed by the authors' observation as students showed better engagement and excitement during and after the activity. As a result, it is envisaged that the students will improve their learning as they are more engaged during the teaching session (Coates, 2005; Graham *et al*., 2007). To extend from this argument, it is highly likely that engaged students will progress further in their higher education life and hence the number of withdrawal students will be reduced (Kuh *et al*., 2008). Due to the initial success of the proposed method, it is envisaged that the jigsaw puzzle game can be used in teaching and learning for other computer science related subjects, such as searching (e.g. regular expression) and file systems (e.g. master file table for New Technology File System).

Nonetheless, the proposed method would be more effective if the following were considered. From the implementation point of view, the complexity of the selected jigsaw puzzle needs to be increased and it should be adequate for adult learners. Otherwise students may find that the proposed method is too simple (i.e. not intellectual challenging) and disengage from the learning (Murray *et al.*, 2004). Also, multiple sets of the same puzzle should be utilised to ensure that students will have equal learning experience as they can solve the same set of problems rather than each faces a subset of the problems individually (e.g. only files with header being missing). From the evaluation standing point, a comprehensive questionnaire should be developed, allowing other aspects of the proposed method, such as its effectiveness in students' learning on the chosen topic, to be assessed. Also, a more comprehensive questionnaire will enable sophisticated statistical analysis (e.g. correlation) being applied to understand the usefulness of the proposed method.

5. Conclusion

This paper has presented the use of a novel game-based learning method to demonstrate the data carving concept via jigsaw puzzles to improve student engagement and hence reduce student withdrawal rate within the computer science domain. Also, feedback from the students shows that the proposed method is effective for enhancing their learning. In future, an enhanced version of the proposed method will be devised and its usefulness will then be investigated.

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