Engineering Education Gamification: A Framework and Learners’ Satisfaction Measurement on Case Study of Engineering Ethics Topic

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Abstract
Nowadays, using traditional technique for delivering engineering education is not fulfilling the market requirements (Phade et al., 2019; Zhao et al., 2019). Gamification is a trend in education where Virtual Reality (VR) technology could be part of it (FUJIMOTO, SHIGETA & FUKUYAMA, 2016). In addition, engineers are required to have continuous education due to their work needs. Engineering ethics as a fundamental topic for both engineers & engineering students use to be explained using traditional education method. According to the Saudi National Anti-Corruption Commission “Nazaha”, 69% of employees did not read their codes of ethics, where 85% of the employees did not receive any training course regarding to their work or the Nazaha’s code of ethics. This study focuses on investigating the acceptance level of gamification in engineering education in Saudi Arabia. This work used the course about professional ethics for engineers as a case study. For this research, a survey is conducting. The results illustrate that gamification might enhance learning experience. In addition, it shows that the traditional way of delivering the topic affected the students understanding level. Furthermore, the traditional method reduced the participants’ enjoyment level. This research will be extended to the implementation of gamification on engineering ethics.

Keywords:

Introduction:
Using games for education purposes increased rapidly (FUJIMOTO, SHIGETA & FUKUYAMA, 2016). Gamification is a terminology illustrate the use of games principles and game-design elements for non-gaming purposes such as educational intentions (Huotari & Hamari, 2012). Nowadays, the market demands trained engineers, who could accomplish complex duties in their work with highest efficiency and effective way. From the other perspective, it is expensive for universities to provide the needed practical training to all students to meet the market or industry needs. In addition, providing actual training for engineering students is consumes both time and resources.
Yet, VR technology could be used as an efficient training tool for engineering students with will need less time and resources than actual or physical training for the students (Greiner et al., 2019). It is hard to put the students in such environments filled with practices without the exposure to danger. VR technology, in contrast, is used to simulate these practices within a secure and managed environment. For example, in the field of Civil Engineering, a study is conducted to examine the possibility of moving the Traffic Engineering Field Exercises from its current method as an outdoor activity to be indoor exercises using VR technologies. The results of that work are promising, where it shows that a VR 360-degree video environment can be used as a replacement for the field experience. In that work, the researchers simulated traffic engineering to a VR exercises to minimize if not to exclude endanger to engineers during the exercises time (Jones, Soltaninejad & de Leon, 2019).

Similarly, the researchers for this work aims to study the application of VR in Industrial Engineering (IE) Education. The selected topic as the research case study is the Engineering Ethics course in the undergraduate study plan that is required by most of the engineering programs. This work is about developing a VR game that has different cases and scenarios while each scenario level has multiple outcomes depending on the player’s decisions. The main idea of the game depends on the learner’s decisions throughout the different levels of the game. Targeted learners for this game are both engineers and engineering students in different undergraduate programs of engineering disciplines. As part of the big research, the current work aims to design the big research framework and investigate the learners’ acceptance level of Engineering Education Gamification (EEG). Learners are selected as a group of the IE Education stakeholders. EEG expected to enhance the students understanding level of the codes of ethics that they learn.

**Literature Review:**

VR technology is described as a computer-rendered simulating three-dimensional images or environments; it gives the user the ability to interact with these environments using electronic devices. This terminology was first used in the 1960s and then it started to spread out (Freina & Ott, 2015). VR has more than one technology. These technologies were used in different fields: Educational, scientific, industrial, recreational & many more. Yet, its most important implementations are in the manufacturing industries. (Choi, Jung & Do Noh, 2015).

As mentioned, VR technologies have been used in education with different forms. It has been applied in the surgical education by creating a surgical simulator.

When the surgery is too dangerous or too expensive, it is better to simulate it and to experience it before engaging (Satava, 1995). This technique will definitely reduce the risk factors in human lives at this type of surgeries. VR technologies give the user the ability to interact with the subject, which increases users focus rate and confidence level. Previews research on VR implementation in Education shows the high contribution level from the students. The students high engagement level implies the increase in awareness level, which impact the level of gained knowledge. On the other hand, VR technologies disadvantages are mainly associated with the costs and time constrains for developing such an environment and then it validation testing (Pantelidis, 2010).

In the Engineering disciplines, VR technologies showed its strengths in multiple areas. VR technologies implementation has a powerful impact in engineering field. This impact is notable when it came to safety of the construction engineers and how it is unsafe for fresh engineers to work in such environments. VR technologies showed its usefulness to guide those engineers about how to work under hard situations (Zhao & Lucas, 2015). These technologies also presented its utility in the traffic engineering learning where students had to go out and be exposed to the dangerous and unsafe conditions in the traditional way for learning this topic. That research results were promising and the researchers, in that work, presented their interests on improving their work by collecting more accurate data (Jones, Soltaninejad & de Leon, 2019). This technology implementation in Engineering Education reduces the costs in the long term, reduces if not eliminate the risk, and gives the users the chance to experience the complex and dangerous tasks within a safe environment. This opportunity was hard for learners to approach within a safe environment. VR technologies is for simulating real problem within harmless setting (Abulrub, Attridge & Williams, 2011). Furthermore, VR once again showed its positive potentials in manufacturing engineering where researchers developed a craft production simulator that helps engineering student to design cars in a creative and innovative ways while achieving low costs. The main purpose of their case is to give the engineers a responsive and interactive environment while decreasing the waste of materials (Zhao et al., 2019).
Based on the literature review, the researchers found that none of the papers is conducted on any industrial engineering topics except one or two that are conducted on a topic under the manufacturing area of knowledge. Yet, most of the reviewed literature shows the promissory of the VR technology applications on different engineering disciplines. In addition, the case study is selected due to a recommendation out of a study conducted by “Nazaha” which included more than four thousands and seven hundreds participants. That study results shows that around 69% of the participated employees did not read the code of ethics. Moreover, around 85% of the participants stated that they did not receive any kind of training related to the code. “Nazaha” recommended training the employees and conducting specialized workshops on principles and ethics contained in the code of Conduct and Ethics for each group of employees. Thus, the big research objective is to give the engineers virtual environment to practice their knowledge level. Moreover, to help both current and future engineers gain the recommended training about the code of Conduct and Ethics for each group of engineering disciplines. The research first starts by studying the acceptance of the idea and the learners’ viewpoints about it.

This research contribution to the literature is mainly about the implementation of VR technology in an IE area of knowledge that is not examined in the literature before. Case study of a course about Professional Ethics for Engineers is selected due to many reasons. First, even though it is a very fundamental topic yet it plays a major role for all engineering disciplines and in all engineers’ profession working areas. Second, this research focuses on the implementation of VR technology in Engineering Ethics course since there was no search investigated the VR efficiency in this topic or its area of knowledge. The advantage of implementing VR technology in Engineering Ethics course is to help learners and educators measure the learners’ knowledge in ethics. In addition, this application showed let learners express the importance of their field and their work codes of ethics. It will help learners know the consequences of their decisions and show them the effect of their current decisions of their careers future.

**Methodology:**

To establish the research, a framework is designed to construct the research main stages as shown in Exhibit 1. The framework shows the researchers plan to design the VR technologies implementation in IE Education. The current work, which is the application of the first two stages of the framework focuses on reviving the literature about the work and similar research in the past 20 years, identifying the gap in the literature, and understanding the possibility of this type of application in the IE Education. To investigate the acceptance level of the learners on this idea a survey is conducted. Survey results were used to examine the learners’ perspective(s) and their thoughts about the expected success of VR technologies implementation in IE Education. The data is collected from a sample of Engineering Ethics learners in Saudi Universities.

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**Exhibit 1: The research framework.**
The first stage was about reviewing the publications about similar or related research for about the past three decades. Then, the collected information was summarizing. The summaries information shows the pros and cons of the VR technologies implementation in education and especially in Engineering Education.

The second stage was about collecting data about the learners’ acceptance rate of this idea. For the acceptance level, measurement a survey was designed. Then, a pilot study was conducted to check the survey quality. The first version of the survey is designed as an electronic survey. The survey is divided into three parts each part has a set of questions focuses on one main idea of the research objectives. The survey validation was measured by distributing it on four engineering students and then their feedback is documented. As a result, for this pilot study, the researchers found that on average the participants took 5 minutes to finish filling the survey. That information is corrected at the introduction of the survey with was mentioned as three minutes on that first draft of the survey. In addition, some participants did not understand the meaning of “B.Sc.”. Thus, the researchers decided to change it to “undergraduate engineering degree”. Moreover, some students did not take any course of ethics yet and they could not answer a part of the survey since it is targeting only those who take or taking the course. However, the first design of the survey was asking to answer all the questions in order to submit the questioner. Because of that issue, the survey is modified to have a mandatory exist way for the participant who did not take or taking the course during the data collection time. By that, all participants who took the course or taking it during the data collection time were still forced to answer all the questions before submitting the survey. In addition, the list of choices for the fifth question of Part two in the survey was not including all the needed options from the participants’ perspective. Thus, this question is changed from a multiple choices to an open-ended question. Further, participants feedback mentioned that fourth and fifth question of part three of the survey are the same while the researchers believe in that they are very different. Therefore, the researchers solved the issue by bolding the important words in both questions to make them notice and help the participants to understand the different in a better way. In addition, during the pilot study, the researchers observed that the participants used multiple names for the same university (School name). Consequently, the researchers decided to change that question type from an open-ended question to a drop-down list for selecting the answer by making a list of universities names. Also, the researchers changed the type of the question about the studying major selection from a multiple choices to a drop-down list question; since there is too many choices of engineering majors to select from and the list is made in an alphabetic order to be more organized and easier in finding the participants school name. Finally, the researchers changed the wording of the multiple answers of one of the questions in part one of the survey to remove the confusion about it. After that, the final version of the survey was ready for distribution. The electronic survey URL was distributed using different social media channels for more than three thousand person. After one week, around 145 responses was collected. Then the data was analyzed as shown in the result and discussion section. The steps of the first two stages mentioned before were summarized in Exhibit 2.

Exhibit 2: Research methodology

Third stage is planned to be an interview for the educators to understand their perspective(s) on using the VR technologies in IE Education. After that, the logical models should be created with the learners and educators involvement. Next, is to work on the physical model and testing its efficiency. Stakeholders’ feedback will help in
modifying both logical and physical models. Next, the system will be implemented. Players of the game will be given different scenarios where the learners/players’ decisions in each scenario will affect the scenario’s outcome in the game and it will show the learners/players’ the consequences of his/her decision. By this method, the learner will be apple to know what could happen if he/she decided to do something unethical and what would happen if he/she selected the ethical option in the game.

Results and Discussion:

The survey results are divided into three main areas. First set of question focused on presenting the topography and diversity of the participants of this survey. The second part is mainly focuses on providing information about the participants’ acceptance level on the current method of the topic delivery, which is called the traditional way of education. The third part of the survey is about the participants acceptant of the VR technologies integration in the engineering education topic and specifically in the Engineering Ethics course(s) learning. The research survey focuses on Saudi schools. The main limitation of the work is about the education state which just focused on engineers and engineering students due to the purpose of the research. The total 145 reopeners were more than 53% of the participants had taken or currently taking at least one course about engineering ethics during their undergraduate studies.

For the first part results, the researchers found that the participants are from 18 different schools inside Saudi Arabia as shown in Exhibit 3. As shown in Exhibit 3, around 35% of the participants are from the University of Jeddah, The researchers’ affiliation. This result was expected due to the researchers’ connections in that school comparing to other schools in the country. Furthermore, most of responses came from engineering students and exactly from male participants, which is about 77% of the total participants as shown in Exhibit 4. This result is also expected due to spread of the males engineering departments in the Saudi schools and the age of these departments or collages comparing to the females sections which is opened recently for women to get their engineering degrees from some of the big Saudi universities. The ministry of education in Saudi Arabia started the engineering programs for woman in the last past few years.

Exhibit 3: Participants’ home schools
Exhibit 4: Participants’ genders and status

In addition, most of the participants are from the young generation who are between 18 and 30 years old, which are presenting around 90% of the participants as shown in Exhibit 5. Again, this result is expected since most of the participants are still students in different engineering schools as shown in Exhibit 3 and Exhibit 4.
From the second part of the survey, the result shows that at least 75% of the participants took at least one course about engineering ethics during their undergraduate programs. Thus, engineering ethics is one of the important topics which is part of most if not all engineering disciplines and undergraduate programs. Exhibit 6 shows that only 8% of the participants believe in that studying a course about professional ethics for engineers during their undergraduate studies is not important. Furthermore, the results show that around 64% of the participants stated that their understanding level of the course material was between very weak and good understanding level as shown in Exhibit 7. Yet, it is one of the fundamental and low-level courses, which supposed to be easy to understand by most of the learners. In addition, only less than 40% of the participants did enjoy or are enjoying taking the course material using the traditional way. These results imply that the course has venues of improvement in the way of teaching or delivering it from one perspective. From another perspective, an improvement could be done by technology involvement in the education process of this course, which will increase the learners’ understanding and their enjoyment of learning the course material.

Moreover, many responses agreed and feels that there is a part or more of the education process of this course could be improved. Different reasons are mentioned in the collected data. Most of these reasons are related to the deliverable method of the material, the evaluation process and class duration. Furthermore, some of the responses mentioned that it is difficult to learn this type of material without a practical or helpful tool to enhance the scenarios understanding by the learners.

For the third part of the survey, the result illustrates that around 42% of the participants did not experience the use of any VR technology before as shown in Exhibit 9. Yet, most of the participants, around 66%, are exciting to see the use of a VR technology in the teaching process of engineering ethics course as shown in Exhibit 10. In general, the result shows that the participant believe in that gamification of Engineering Education using VR Game will enhance...
students’ understanding of the Engineering topics. Exhibit 11 shows that around 63% of the participant believe in that using VR technology in the Engineering Education process will enhance the learners’ understanding of the topics. Moreover, around 70% of the participants believe in that using VR Game in the Engineering Education process will make Engineering courses more interesting for students, as shown in Exhibit 12.

Exhibit 9: Participants’ experience of using VR technology.

Exhibit 10: Participants’ interest level of using VR technology in the teaching process of ethics course.

Exhibit 11: Participants’ view of using VR technology in the Engineering Education process.

Exhibit 12: Participants’ interest level of using VR technology in the teaching process of engineering course.

For more specification, around 60% the participants believe in that using VR Game in the Engineering Ethics Education will increase the learners’ interest in the course, as shown in Exhibit 13.
Exhibit 13: Participants’ view of using VR technology in the Engineering Ethics Education.

Exhibit 14: Participants’ interest level of using VR technology in the teaching process of the engineering ethics course.

Finally, as the results shows around 60% of the participants are interested in learning this course specifically using a VR technology as game. Thus, the researchers believe in that using VR games in Engineering Ethics is a promising way that will increase both understanding and enjoyment of the topics for learners.

Conclusions and recommendations:

In general, VR technology implementation shows its valid results in multiple areas. As an educational tool, VR technologies also has shown its usefulness in providing better understanding, more practical environment with minimizing the costs, time and wastes within a safe and harmfulness areas for learners.

The market nowadays is demanding trained and more practical educated engineers who are ready to perform their job, the research main focus is too investigate whether engineers and engineering students are ready to use advanced technologies such as VR technologies in their education process to help enhance their practical education side. As a first stage of the big research, the researchers created a framework and selected a fundamental and very important course that is the Professional Ethics for Engineers as the research case study. Motivation of the researchers’ decision came from Nazaha’s study recommendation, which recommended giving all engineers a proper training about the ethics code they need in their work places and environments.

An electronic survey was published and sent out to approximately more than 3000 person using URL via different social media channels. A total number of 145 responses was received within a week period, the survey shows auspicious results and stating that the responders are seems to be ready for a major change in their education process and methods.

To sum up, most of the response shows that the engineers and engineer students are not highly satisfied of using the traditional way of learning ethics course. The results also shows that the participants acceptance level of the use of VR tool in engineering education and especially in the engineering ethics course(s) is demanding. Gaining learners’ opinion help in enhance their educational experience. Nowadays, the world is changing rapidly due to the new technologies alterations. Thus, educators always need to keep up with new helpful technologies tools like VR technologies, which may have a huge impact in the education field. Using VR technologies will give the learners the advantage of focus more on the practical side of the knowledge instead of the emphasis on the theoretical material that will not make learners ready to work market.

For the future work, after significance of the learners’ acceptance of using VR in their education, next step it to investigate the educators’ perspective(s). The instructors’ point of view should be collected. Then, based on both learners and educators’ perspectives, the set of logical models and the initial physical model will be created for the proposed system. After that, the models should be tested for verification and validation. At the end, the researchers will seek different stakeholders help to examine the system reliability and feasibility and gather the feedback from different groups of stakeholders for the system modification and improvement.
References:


Biographies:

Muslih Al Zahrani is an Undergraduate student, in Industrial and Systems Engineering Department at University of Jeddah. His research interests are in User Experience (UX), Human-Computer Interaction (HCI) and game development (GD). Muslih Studied in Al Faisaliah School for gifted students, participated in many programs from the gifted management at Jeddah won an award for developing a videogame for his math class, Muslih has participated in National Olympiad for scientific Creativity three times and got to the next stage two times.

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