An Innovative Educational Environment Based on Virtual Reality and Gamification for Learning Search Algorithms

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Abstract— **Search algorithms constitute an important domain of computer science and is considered necessary for students and freshmen to get a deep and complete understanding of their operation. In this work, we present an innovative 3D virtual reality educational environment that aims to assist tutors in teaching and students in better learning the search algorithms. The educational environment utilizes innovative educational infrastructure and pedagogical approaches based on visualization of procedures and learning activities that rely on gamification to promote deeper understanding of the challenging concepts of blind and heuristic search algorithms. Algorithm visualization approaches in the virtual environment aim to help students connect abstract concepts and procedures to concrete experiences and examples which promotes robust learning. Learning activities based on the principles of gamification was designed to actively engage students and make learning more entertaining and efficient. The educational environment has been evaluated in real classroom conditions and the evaluation results indicate that the utilization of suitable learning activities in terms of students' active engagement and can motivate students and improve learning efficiency.**

Keywords virtual reality, algorithm visualizations, teaching search algorithms, 3D virtual worlds, learning efficiency

I. INTRODUCTION

In recent years, rapid development of technology has changed the way that educational platforms and learning activities are provided to learners. New technologies like 3D virtual reality can open up new horizons in education and have the potential to offer new, innovative and more efficient learning activities and training procedures to students [4]. The 3D virtual reality environments can offer various immersive learning procedures and provide students the capability to explore and examine how different procedures are conducted thought appropriate visualizations [12].

With the advent of technology and the ever growing demands young students face, the issue of learning in 3D virtual reality environments has become a desired reality. More and more efforts are being made in order to implement innovative technologies that can help students learn efficiently and without being disconnected from the academic environment. The question remains whether these groundbreaking approaches can successfully improve the conventional face-to-face lesson or even replace it and if so, what are the steps one needs to follow in order to develop a "virtual curriculum".

Virtual reality educational environments can support a wide range of educational procedures and also a quite broad spectrum of training and learning activities. They can be utilized to assist tutors in teaching and also students in learning and most of all to enhance the quality and the efficiency of educational procedures. Teachers and tutors can utilize virtual world educational environments to assist themselves in better teaching several aspects of their courses. Indeed the capabilities that virtual worlds offer can provide new opportunities to teachers to formulate their courses' curriculum and conduct lectures. Virtual reality educational environments are useful for facilitating participatory learning processes and can lead to better cohesion and cooperation among students' [17][9]. They have been used with great success in challenging domains [15] to offer immersive learning processes to students and give them the opportunity to explore and understand how various procedures are conducted and how specific constructions operate via proper simulations and visualizations [12].

Search algorithms constitute a fundamental domain of computer science and artificial intelligence and have various applications in a wide range of problems and procedures [1]. In higher education, it is considered necessary that students learn efficient and in depth the way that algorithms function and also be able to accurately apply them in various problems and situations. However, the domain of search algorithms is acknowledged by many tutors to be a difficult domain to teach and also a very hard and complex domain for students to deeply understand and correctly implement. Indeed, the domain consists of complex cognitive and error prone processes that traditional education fails to cover and efficiently teach.

Specifically, from a tutors' perspective, teaching and explaining how search algorithms operate is challenging and in general requires a lot of explanations, illustrations and teaching aids other than blackboard to assist students in understanding algorithms better [1]. In addition, from a

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learners' perspective, the algorithms constitute a challenging task for students to deeply comprehend as they usually model complicated concepts and also refer to abstract mathematical notions [19]. When students learn new abstract concepts such as algorithm heuristics, it can be hard for them to comprehend without appropriate connection to concrete examples [14]. Visualization of their functionality and interactive application in various exercises and learning activities can help students connect abstract concepts and procedures to concrete experiences and examples. Furthermore, learners can recognize and comprehend virtual graphical representations faster and deeper than textual instructions and static representations [19]. Moreover, traditional learning approaches lack in delivering efficient learning activities and fail to engage, motivate and enhance students' cognitive comprehension and knowledge construction. So, they can become a very boring task for learners. On the other hand, learners get excited when using electronic means such as educational games and learning in virtual worlds and participate actively in the learning procedures.

In this work we present an innovative educational environment that aims to assist students to learn more efficiently and to a greater depth the way that search algorithms operate. The educational environment is based on 3D virtual reality. In the environment, various learning approaches and training activities were developed aimed at assisting students in learning effectively in an entertaining way. The learning affordances of the virtual world were properly designed to scaffold both students' efficient learning and teachers' lecture conduction. The term "affordances" refers to the characteristics and potential uses that individual learners felt that virtual world had to offer to them. In other words, different learners saw different potential applications and implications in the range of tools to which they were exposed. The virtual world environment also allows student interaction with various virtual procedures, operations and constructions. In the virtual environment students can solve problems in mazes by correctly applying specific blind or heuristic search algorithm. Specifically, students can participate in learning activities that require of them to simulate the way that an algorithm will function in a maze in order to solve it and students have to properly move their avatar according to the algorithm. The evaluation study conducted in real classroom conditions revealed very encouraging results regarding the learning capabilities of the virtual environment.

The rest of the paper is structured as follows: Section II presents the VR-ALGO educational environment, illustrates the educational infrastructure and analyzes its training capabilities. Section III, presents the educational approaches and the learning activities designed and offered to students in the 3D virtual world. Section IV presents the evaluation study conducted in real classroom conditions and analyzes the results gathered. Finally, Section V concludes the paper, describes the experiences gathered and provides directions for future work.

II. THE VIRTUAL REALITY EDUCATIONAL ENVIRONMENT

The 3D Virtual reality educational environment was developed using the Open-Simulator platform which is a popular and widely used open source multiplatform and multiuser 3D application server [18]. In the virtual environment students and all users are represented as avatars and can move within the world, visit constructions (such as factories, plants etc.) examine 3D objects and interact with them, study educational materials and take exercises and quizzes etc. Tutors can organize virtual classes in a synchronous or asynchronous way. The use of an avatar in the virtual world provides a sense of presence and awareness and enhances the ability to interact with the 3D constructions in the world and also communicate and collaborate with the other students and the tutor.

A student entering the 3D Virtual reality for the first time will find his avatar in front of a series of instructional boards, presenting the basic controls of the 3D Viewer Software. Following these instructions the student will be able to move around with his avatar, control the camera, change his avatar's appearance and communicate with other avatars through various ways (text, gestures, sound from a microphone etc.).

The virtual classrooms can support tutors' lectures to groups of students and simulate at some degree the physical classrooms in a real school. The tutors can schedule a lecture at a specific room of the virtual world to take place a specific time and date. The students and the tutors can have a common place to meet and communicate regardless of their physical locations. Furthermore, the Virtual Library that was developed contains all text material regarding the search algorithms and artificial intelligence domain. The educational materials are presented as books and are organized in shelves. The student can select a book by clicking on it in order to open it and study corresponding theory in text format on the presentation screens.

Figure 1. A student in a small auditorium

III. Learning Approaches and Training Activities

The 3D virtual world offers immersive learning processes to the students and gives them opportunities to explore how algorithms operate via proper simulations and visualizations. When students learn new abstract concepts, it can be hard for them without appropriate connection to concrete examples [14]. In this line, visualization of algorithm operations can help students connect abstract concepts and procedures to concrete experiences and examples. Visualizations have been proven to be an effective teaching-learning resource at the tertiary level [3]. Algorithm visualizations and animations are well pointed to assist students in learning algorithms [11]. Indeed, the visualizations, when used properly in a learning process, can help a student to deeper understand the way an algorithm operates, by demonstrating how it works and how it makes proper decisions based on parameters, such as heuristic and cost functions [10] [16]. In the virtual world and the mazes every decision that the algorithm makes, such as for example which node(s) to expand/visit, is properly presented and explained to the student. The visualization explains how a decision was made by the algorithm and how the values of the parameters, such as the heuristic and the cost functions (if any), were calculated for each algorithm's step. In the virtual environment, a noticeable aspect of algorithm visualizations is that they have been developed according to the essence of student active learning. More specifically, the visualizations have been designed based on the principle of engaging the student as much as possible in the demonstration process and making student to think hard at every step of the algorithm's animation. The principles of active learning maintain that the more the users directly manipulate and act upon the learning material, the higher the mental efforts and psychological involvement and therefore the better the learning outcome [13].

In this spirit, during an animation demonstrating the implementation of an algorithm in a maze, the animation can stop at a random step of the algorithm and ask the student to specify some aspects regarding the operation of the algorithm. The animation may engage students and request from them to specify the next grid on the maze to be visited or ask them to justify why a movement was made. In general, such justifications mainly concern either the last one action conducted by the algorithm or the specification and proper justification of the next action to be conducted. The interaction with a student and the questions asked are either interactive questions or multiple choice questions. The interactive exercises may necessitate student to interact with the virtual world and the maze and specify the next move based on the algorithm's step. For example, during visualization, it can pause and ask the student to specify the next algorithm's step by selecting the proper next grid. In case of a correct student's answer, it can also request from student to justify the reason, by offering additional multiple choice question(s). In case of an erroneous answer, knowledge of correct response and proper explanations are immediately offered to the student. After an interaction with the learner, the animation process continues and during an algorithm's visualization in an example exercise, multiple interactions with the learner can be made.

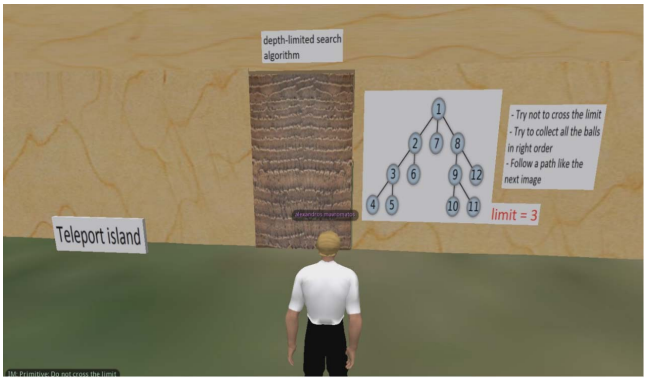

Figure 2. Starting a maze game in the virtual world environment.

Students in the virtual world can also participate in various learning activities based on gamification that are oriented to be entertaining and playful and that are designed to be more challenging and fun oriented. In this spirit, students have to solve predetermined mazes in the virtual world under different conditions and in a specific amount of time, something that can make the playing mode more challenging and motivating. Also, in this mode students can complete maze levels and proceed to next ones that are more complex and challenging. The various levels are designed in the spirit to necessitate students to apply a specific search algorithm and properly move in the maze simulating the way that the algorithm functions in order to accomplish the level's requirements. The level requirements in general concern user to reach in the maze a specific point, exit and also eat dots. In this approach, students are requested in a maze level, starting from a random position, to reach the goal (e.g. exit, specific item etc.) by moving based on the specific algorithm that the maze specifies.

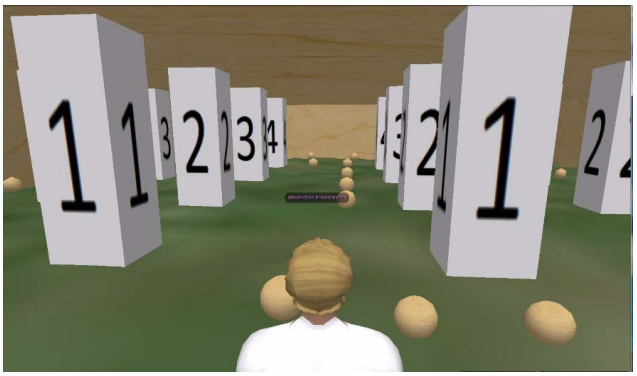

Figure 3. User inside a maze requiring to simulate the functionality of an algorithm

The student using the keyboard can move the avatar in the maze and specify the direction to follow. As the student proceeds, subsequent levels are more complex in terms of maze characteristics, number of ghosts in the maze, goals to achieve and most of all, the complexity of the algorithm and its parameters that are requested from student to apply.

IV. Experimental Evaluation

A study was conducted in order to evaluate the virtual reality educational environment and provide an insight of the degree it assists students learning. To this end, a detailed experimental evaluation study was designed and implemented. Participants of the experiments were students of the Artificial Intelligence class at our university's department. All students were in the 4th year of their study and their age ranged from 21 to 23 years. The students had attended AI course lectures on artificial intelligence algorithms and had the necessary knowledge on background topics. The main objective of the experimental studies was to obtain a comparative assessment of the effectiveness of the learning activities afforded by traditional learning and virtual reality enhanced learning in the educational environment, by comparing the effects of different feedback scenarios on learning. In the experimental study we followed a pre-test/post-test evaluation approach.

A. Method

The purpose of the study was to examine the efficiency, the motivation and the effectiveness of the virtual reality environment in assisting students in learning the AI search algorithms. In the study, the participants were 44 students from those enrolled in the artificial intelligence course. Initially, all the students were randomly divided into two groups of 22 students each, namely GroupA and GroupB. The rates of girls and boys in group A was the same as those in group B.

We followed a pre-test, post-test study design followed by a questionnaire survey to assess the learning effectiveness, the learning attitudes and the motivation of students and also for gathering students' attitude, opinion and experiences about the learning activities of the virtual environment. The experimental procedure used to evaluate the virtual environment is illustrated in Figure 3.

Initially, all the students (groupA and groupB) took a pre-test to evaluate the prior knowledge on AI search algorithms. The pre-test was used to ensure the two groups had equivalent prior knowledge on AI search algorithms. The pretest consisted of eight questions on various aspects of the blind and heuristic search algorithms and the duration of the pretest was 30 minutes. After students submitted their answers to the pretest, all their answers were marked on the scale from 0 to 100 points. The groupB used the virtual world for two weeks while students of GroupA used the traditional learning. Then, all the students took a post-test. The post-test consisted of eight exercises and the students were given 30 minutes to complete the test and submit their answers. The difficulty level of the post-test was the same as the post test and once again the post-test was conducted in the computer room of our department. After the learning activities the students were asked to fill in a questionnaire and express their affect, opinions and experiences towards the virtual reality environment and assess its learning assistance.

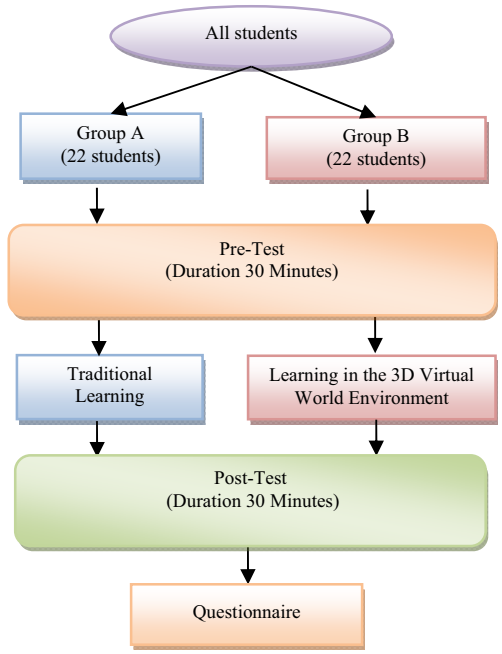

Figure 4. The phases of the experimental evaluation study

B. Results and Discussion

An independent *t*-test was used on the pre-test. The means of pre-test for groupA and groupB were 37.27 and 36.31 respectively. The results showed no significant difference among the students of the groups ($p=0.56 > 0.05$, $t=0.54$) so it was concluded the two groups had equivalent prior knowledge before the experiment.

The ANOVA results indicate the differences in post-test scores are statistically and significantly different between the two groups ($F=78.43$ $p=0.00<0.05$). Finally, the results showed that the performance of the students of groupB, who used the educational environment, was better than that of control group. Table I presents the post-test results, in which the mean values of the post-test scores were 54.32 for Group A, and 74.54 for Group B.

Table I. Analysis of the Post Test Results

Groups	N	Mean	SD
GroupA	22	54.32	8.06
GroupB	22	74.54	7.05

In addition, the leaning gains of the students were calculated and in next Figure (Figure 5), the learning gains diagram of both groups is presented.

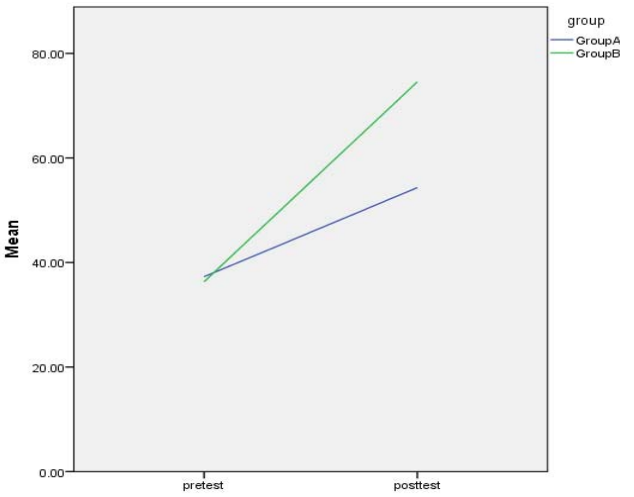

Figure 5. The learning gains diagram

The results demonstrate an increase in the post-test scores of both groups indicating that the students have learned in both cases. However, Group B performed much better than Group A. In the post-test they made fewer mistakes, achieve better scores and got a deeper understanding of the search algorithm operation.

Subsequently, the students of the experimental group were asked to fill in a questionnaire that included questions for evaluating usability of the virtual environment, stating their experience and their opinions about the learning process. The questionnaire included 15 questions. The questions Q1-Q12 were based on the Likert scale (1: not at all, 5: very much). Questions 13-15 were open type questions and concerned strong and weak points of the environment and the learning activities designed or problems faced and also improvements that can be made to the educational environment.

TABLE II. QUESTIONNAIRE RESULTS

Q	QUESTIONS	ANSWERS (%)				
		1	2	3	4	5
1	I enjoyed using the virtual reality educational environment	0	0	4.5	9.1	86.4
2	The interface of the virtual reality educational environment is easy to use.	0	0	9.1	13.6	77.3
3	The virtual reality educational environment made me more active in the course	0	0	4.5	9.1	86.4
4	The virtual reality educational environment can increase my motivation	0	0	9.1	13.6	77.3
5	The virtual reality educational environment can enhance my engagement in the course.	0	0	4.5	9.1	86.4
6	The virtual reality educational environment can enhance my learning interest.	0	0	9.1	9.1	81.8
7	The use of the virtual reality educational environment for learning is more interesting than other ways of learning.	0	0	9.1	13.6	77.3
8	The virtual reality educational environment assisted me in learning more effectively the search algorithms.	0	0	9.1	9.1	81.8
9	The virtual reality educational environment assisted me in getting a deeper understanding of the functionality of the algorithms after playing.	0	0	9.1	9.1	81.8
10	The interaction with the visualizations of the algorithms assisted me in understanding the algorithm way of function.	0	0	4.5	4.5	90.9
11	Using the virtual reality educational environment provides me with new way of thinking about AI search algorithms	0	0	4.5	9.1	86.4
12	Will you recommend the virtual reality educational environment to other classmates and be integrated in the course curriculum?	0	0	4.5	13.6	81.8

After analyzing the students' responses to the questionnaire, the reliability of the questionnaire was checked using the Cronbach's alpha [4] metric was 0.79 and the reliability of the scale was determined to be good. So, the questionnaire is reliable and so secure conclusions and findings can be derived.

The questionnaire results indicate that the students' feeling about the virtual reality environment was very positive, as summarized in Table 2. Results point out that the majority of the students enjoyed studying and playing with the virtual environment (86.4%) and a considerable portion of them (77.3%) found the interface of the virtual environment easy to use. Also, 77.3% of the students indicated that the virtual environment was more interesting that other educational approaches and ways of learning. In addition, a great portion of the students stated the virtual environment increased their motivation (77.3%), engagement (86.4%) and interest (81.8%) and made them more active in the course (86.4%). Regarding the learning efficiency of the virtual environment, students stated that the virtual environment helped them in learning more effectively (81.8%) and in getting a deeper understanding of the algorithms (90.9%) after playing. In addition, the interactions with the virtual environment during the algorithm visualization assisted students to understand the way an algorithm function (81.8%). In general, the results showed that the virtual reality and the learning activities designed assisted the students in getting a deeper understanding of the AI search algorithms and the way they operate in an entertaining way. Moreover, approximately 86.4% of the students stated that the virtual environment can provide them a new way of thinking about AI search algorithms. Finally, the majority of students (81.8%) suggested the virtual environment to be integrated in the course curriculum and be used by the next year students.

V. Conclustions and Future Work

Search algorithms constitute a fundamental domain of computer science and artificial intelligence and have various applications in a wide range of problems and procedures. It is considered necessary that students learn efficient and in depth the way that they function and also be able to accurately apply them in various problems and situations. In the literature, several studies point out that search algorithms constitute a difficult domain for students to master. In this work we present an innovative educational environment that aims to assist students in learning search algorithms more efficiently and to promote deeper learning. The education environment is based on virtual reality and several learning activities and pedagogical approaches that rely on gamification and active learning are designed and offered to students. The educational environment has been evaluated in real classroom conditions and the results were encouraging. Findings indicate that the visualization of algorithms and the utilization of suitable learning activities in terms of students' active engagement improved students' comprehension and learning efficiency. Also, results indicate that the virtual reality environment is a very efficient mean to increase students' interest, motivation and most of all their knowledge construction.

The findings of the study provide various directions that future work can focus on. Firstly, a bigger scale evaluation could be conducted in order to provide a deeper and more analytical insight of the learning efficiency of the training activities offered. A main direction for future work concerns the design of collaboration learning approaches in the virtual reality educational environment and the examination of their efficiency on students study and cooperation with their peers. In addition, another direction concerns the integration of learning analytics mechanisms to record students' behaviour and actions during the learning activities and also the utilization of educational data mining techniques to analyze and extract knowledge regarding students learning construction.

References

[1] Alse, K., Lahoti, M., Verma, M., & Iyer, S. (2015, December). GATutor: A guided discovery based tutor for designing greedy algorithm. In *2015 IEEE Seventh International Conference on Technology for Education (T4E)* (pp. 61-68). IEEE.

[2] Baecker, R. (1998). Sorting out sorting: A case study of software visualization for teaching computer science. Software visualization: Programming as a multimedia experience, 1, 369-381.

[3] Banerjee, G., Kenkre, A., Mavinkurve, M., & Murthy, S. (2014, July). Customized Selection and Integration of Visualization (CVIS) Tool for Instructors. In *2014 IEEE 14th International Conference on Advanced Learning Technologies* (pp. 399-400). IEEE.

[4] Burkle, M., Kinshuk. (2009, September). Learning in virtual worlds: The challenges and opportunities. In *CyberWorlds, 2009. CW'09. International Conference on* (pp. 320-327). IEEE.

[5] Christopoulos A., Conrad M. and Shukla M. (2016). How Do Students 'Really' Interact with Virtual Worlds? - The Influence of Proper Induction for Virtual Interactions.In Proceedings of the 8th International Conference on Computer Supported EducationISBN 978-989-758-179-3, pages 43-54. DOI: 10.5220/0005755700430054

[6] Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. psychometrika, 16(3), 297-334.

[7] De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology*, *41*(1), 69-85.

[8] Gregory, S., Lee, M. J., Dalgarno, B., & Tynan, B. (Eds.). (2016). *Learning in Virtual Worlds: Research and Applications*. Athabasca University Press.

[9] Grivokostopoulou, F., Perikos, I., Kovas, K., & Hatzilygeroudis, I. (2016, March). Learning Approaches in a 3D Virtual Environment for Learning Energy Generation from Renewable Sources. In *The Twenty-Ninth International Flairs Conference*.

[10] Hansen, S., Narayanan, N. H., & Hegarty, M. (2002). Designing educationally effective algorithm visualizations. Journal of Visual Languages & Computing, 13(3), 291-317.

[11] Hundhausen, C. D., Douglas, S. A., & Stasko, J. T. (2002). A meta-study of algorithm visualization effectiveness. Journal of Visual Languages & Computing, 13(3), 259-290.

[12] Ku, K., &Mahabaleshwarkar, P. S. (2011).Building interactive modeling for construction education in virtual worlds. Journal of Information Technology in Construction, 16, 189-208.

[13] Lee, M. H., & Rößling, G. (2010). Integrating categories of algorithm learning objective into algorithm visualization design: a proposal. In Proceedings of the fifteenth annual conference on Innovation and technology in computer science education (pp. 289-293). ACM.

[14] Ma, T., Xiao, X., Wee, W., Han, C. Y., & Zhou, X. (2014).A 3D Virtual Learning System for STEM Education.In Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality (pp. 63-72). Springer International Publishing.

[15] Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769-780.

[16] Naps, T. L., Rößling, G., Almstrum, V., Dann, W., Fleischer, R., Hundhausen, C., ... & Velázquez-Iturbide, J. Á. (2002, June). Exploring the role of visualization and engagement in computer science education. In ACM SIGCSE Bulletin (Vol. 35, No. 2, pp. 131-152). ACM.

[17] Pellas, N., (2014). A theoretical cybernetic macro–script to articulate collaborative interactions of cyber entities in virtual worlds. International Journal of Learning and Change,7 (3),156-180.

[18] Ridgewell, W., Kumar, V., Lin, O., Kinshuk. (2011, July). OpenSim Virtual Worlds as a Platform for Enhanced Learning Concepts. In *2011 IEEE 11th International Conference on Advanced Learning Technologies*.

[19] Shabanah, S. S., Chen, J. X., Wechsler, H., Carr, D., & Wegman, E. (2010). Designing computer games to teach algorithms. In Information Technology: New Generations (ITNG), 2010 Seventh International Conference on (pp. 1119-1126). IEEE.

[20] Stefan, L. (2016, April). Virtual Worlds In Online Education And Training-An Evaluation Report. In *The International Scientific Conference eLearning and Software for Education* (Vol. 2, p. 453). " Carol I" National Defence University.