

Developing cognitive processes for improving inventive thinking in system development using a collaborative virtual reality system

Gyöngyi Bujdosó

Faculty of Informatics,
University of Debrecen,
Debrecen, Hungary
bujdosogyongyi@inf.unideb.hu

Ovidiu Constantin Novac

Faculty of Electrical Engineering and
Information Technology
University of Oradea
Oradea, Romania
ovnovac@uoradea.ro

Tamás Szimkovics

University of Debrecen,
Debrecen, Hungary
szimkovics.tamas@inf.unideb.hu

Abstract—Computer Sciences (CS) require inventive thinking from computer science experts. CS education has to pay attention on that field of education, too. Universities have to educate programmers for the future where the CS experts need the most important skills of creativity, invention and innovation. These skills can be developed by using virtual reality. In this paper we deal with those techniques that we used for developing the students' skills on creativity and invention. We supposed that the ability to spatially organize learning materials and working documents and collaborative spaces may stimulate creative thinking. In this method we applied the MaxWhere, an immersive virtual reality (iVR) system that gives wide range of possibilities for cooperative and collaborative work. This iVR system provides many means that can be used for activating cognitive processes and improving inventive thinking. This method provided positive results.

Keywords—*inventive thinking; computer science education; immersive virtual reality; MaxWhere; higher education*

I. INTRODUCTION

In computer science education there are many important focuses to develop. One of the most important is to learn how to design and develop a system, even if it is a smaller web site or a huge and complicated computer software. Designing and developing a software system needs – among many others – creativity, inventive and innovative thinking.

In this paper we present a teaching method that we applied for improving creativity and inventive thinking in computer science education at the Faculty of Informatics, University of Debrecen, Hungary.

Why is it important to deal with creativity and inventive thinking in computer science education? Students on computer science majors have to gain and develop many skills for becoming a computer science experts. In brief, they have to learn how to split the real life processes into algorithmic steps, how to create a system of congruent algorithms from the disjunct steps, how to design a program for effectuate the algorithms, and how

to write the program codes. These fields need skills on reproduction, but on the other hand, they need a high level of creativity.

Educators have to pay attention on improving not only the skills on using and applying new technologies but the skills on inventive thinking.

Students need creativity for having new ideas and for designing those systems that fulfil these new ideas. That is why we have to focus on developing inventive and creative thinking in computer science education.

II. THE APPLIED NEW VR TECHNOLOGIES

First of all briefly we present the virtual reality (VR) technologies that we used in this research.

A. VirCA

We started to use a collaborative online immersive virtual reality (iVR) system, the Virtual Reality Collaborative Arena¹ (VirCA) (see, e.g., [13]) some years ago. VirCA offers tools for collaborative working in a virtual area, even if a project needs remote robot controlling. One of our most important aim was to provide possibilities for our students to find new space for think in a new way. As a first step, we designed a smart virtual book shelf ([4]). In that year the developers of VirCA presented a new project, the MaxWhere, a new virtual collaborative environment that is more flexible and portable and can be used easier in education, too.

B. MaxWhere

MaxWhere² is the first immersive VR operating system that provides convenient three dimensional spaces (with buildings, gardens, beaches, lakes, etc. in them) to its users for creating their own working areas. The system has some default spaces that people can use and where they can design and create their own comfortable working environments. MaxWhere provides

¹ <http://virca.hu/>

² <http://maxwhere.com>

an easy to use interface for applying the designed and equipped environments.

This collaborative and immersive virtual reality system provides possibilities to develop not only working environments in it but applications, and to develop people's own spaces, as well. After drawing a given space with views and objects, it can be imported into MaxWhere and can be used as an immersive virtual reality environment for collaboration (see Fig. 1).

It gives opportunity to use the existing spaces in an easy way for those people who are not programmers or information technology experts, so it can be used for collaboration in various working environments.

The environments in MaxWhere are improvable. Users can design and create more objects, they can choose different backgrounds and surroundings as well as the colors or the number and positions of the objects can be changed.

A point for informational sheet can be inserted anywhere in a given 3D space, at any position. Fig. 1 shows the space that we used for collaboration. In this space, there are browser windows where users can specify the content to be shown. The opened and displayed documents in the browser windows are editable and sharable, users can use them as they do it in the "real" world, outside of the MaxWhere space. It means that people can work together on the shared documents that can improve the users' experience on collaboration.

MaxWhere offers the necessary functionalities for creating a presentation-like environment that contains predefined order for moving between the specified pinned points of the space that contain information. The menus can be seen on Fig. 2. Users can choose between the predefined order, and their own way to discover the contents. The predefined order can be omitted, people can move in the space where they want without any limitation. The space usage is not limited to the walls, people can use the floors, roofs as well as the sky or the water.

MaxWhere provides opportunity to the users to immerse in these environments by using Oculus Rift headsets, as well.



Fig. 1. MaxWhere – A collaborative basic space. There are some predefined browser windows with an assigned display order. The number and the position of these content points can be changed.

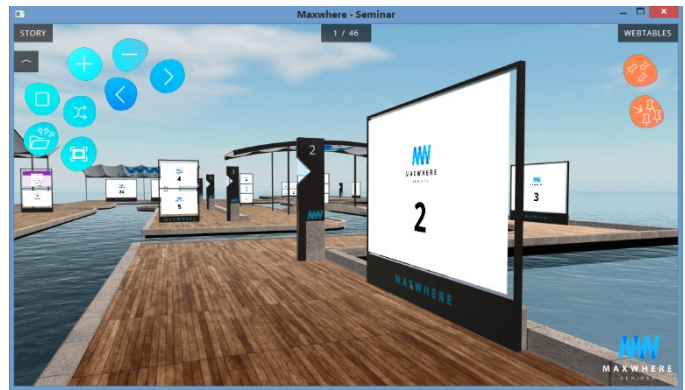


Fig. 2. MaxWhere – Menus can be seen on the left and right side. The most important functions are displayed in the main menus for a simple right click, that make the work fast and easy.

III. NEW INNOVATIONS IN EDUCATION

A. Disruptive Technologies

The term "disruptive technologies" (DT) was introduced to business life by Christensen ([7]) who conceptualized the idea and the principles. New technologies have risks to introduce and apply in businesses. Christensen offered methods how to handle the situations when firms have to apply disruptive technologies, how to reduce the risks of failure. After a while these technologies can become sustaining, but some of them disappear from the market. He offered that companies have to pay more attention and invent more effort into the usage of such technologies and inventions.

In the instructional theory, the term of DT can be used for those technologies which are new and can be used in teaching methods. Christensen describes the disruptive innovation as "an innovation that makes a complicated and expensive product simpler and cheaper and thereby attracts a new set of customers" [8]. The usage of these innovations in education needs more attention and more endeavour from the teachers but can make the teaching process more effective and can motivate the students.

The information technology (IT) brings always new challenges into education. We can mention here the Internet of Things (IoT) that brings wide range of various applications that can be used in the education, too. Sharing economy services were emerging during the last some years. It has features that education can apply, as well. Gamification can be applied in many cases for information transfer and training. Some parts of gamification technology, techniques, innovation and methodology can be regarded as sustainable already but we can use always really new ones that can be classified as disruptive (see some in [9]). Cloud computing is also a characteristic disruptive innovation. VR and mainly the iVR technologies are typical representatives of the disruptive technologies, and there are many innovations in this field which can be called disruptive ([19]).

B. Immersive Virtual Reality

The literature of VR shows that students can use many virtual reality applications in their studies. They can use it to study in various fields, for example, psychology ([1]), chemistry ([20]), language ([21]), marketing ([7]), mathematics ([16], [22]), physics ([15]), engineering ([18]) and many other fields of sciences. Medical education has a great role in developing and using VR for teaching and training students (see, e.g., [17]).

In these systems students can use ready-to-use applications for learning in the VR educator environments, in general.

In our case, the students have to create their iVR environments for fulfilling the specified purposes.

IV. ABOUT THE RESEARCH

MaxWhere inspired us to use MaxWhere for introducing a teaching method that uses this iVR system for motivating students to a creative way of working, and to be inventive in this new, disruptive environment. At the beginning we used the MaxWhere Seminar (version 1.2), later we used the newer version of it, the MaxWhere 1.3.

The system offers many benefits for creative thinking. We supposed that students will be motivated to develop a collaborative environment where they can provide a working environment, an informational space, or a working room with specified tasks for their colleagues, customers or students.

A previous research provided some interesting results about the motivational power of iVR systems in teacher training that we could use during designing the present research. In that research the students had to develop an educational environment for their students ([5]). The students were creative and motivated during their work concerning the place and position of the pieces of information, but the designed communicational channels and methods were on low level.

A. Scopes

In this research we examined the level of CS students' motivation and creativity. Our main aim was to see how the students use these iVR areas for developing an environment. In addition, we wanted to see how they applied the iVR for and during their learning processes.

The main questions were:

- a) Can iVR motivate the students' for working?
- b) Can MaxWhere increase the students' creativity?
- c) Will the students involve the new features that are provided by the new working area for creating their specified purposes? Will they assign tasks for the environment? & What kind of tasks will assign to the environments?
- d) Will they use the iVR for the learning process? Will they use it for collaboration and cooperation with their colleagues in they work outside the classroom? & If they do how do they use it?

B. Methods

Each student had to choose a purpose for the environment. They had to design their environments quite freely, they had possibility to choose and gather the content, and the way of place and display the content for the environment. They could assign tasks to the environments that could make the environments more effective.

The design the spaces, rooms that can fit their pedagogical and didactical goals, and after the design phase they can develop this area. These environments are shareable and this feature has various possibilities for defining roles with special access rights, and gives many options for personalization. A collaborative environment developed in the MaxWhere can be ideal for working together during in-person meetings as well as for a trainings, information mediation, cooperation and collaboration through the Internet.

In our VR Laboratory at the faculty the computers are equipped with the appropriate parts and some additional devices that make possible to run in an iVR system.

We plan to spread the research to more students at more universities. For this, the students and the laboratory will need more computers with strong parameters.

In this research, students got accessibility to the laboratory during a semester. They got a virtual space (Fig. 1). They could use the predesigned objects in the space and they had possibility to insert informational points wherever they wanted. They could design the content, place and type of the information, they could organize the content spatially that gave more possibility to express (and find) the relationships and correlations of the displayed pieces of information. They could collaborate, cooperate, and communicate with their colleagues during their work. Students had possibility to design and create more objects into the space.

Every student had to choose a purpose for the environment. The environment had to have a topic. Students had to collect the pieces of information for the purpose in the specified topic. They had possibility to assign task to those people who will use the environment. The purpose & topic pair had to be unique in the group. They got a list of purposes and topics from where they could choose one, but they could create a new one (outside from the list) if they wanted.

During the semester we talked about the designed and prepared parts of their environments, the issues and problems that were emerging during their work, At the end of the semester we checked the prepared iVR environments. Students used their colleagues' environments. We spoke about the possibilities they applied and about those ones that they did not use.

V. RESULTS

A. Motivation – A Result of Using iVR

As we supposed, students were motivated to work in the iVR. They spent more time with this project (by designing and creating content and tasks in this space) than it was mandatory; i.e., after submitting the results of the subtasks, and accepted them by the teacher, the students did not stop to design and fill

the space by new contents that they collected or created. They did extra work not for fulfilling the course requirements but for fun or to satisfy their interests.

Students collected contents, they created and placed shared document for working together with their colleagues. They assigned various types of document from various media, such as videos, animations, audio files. They linked other VR spaces, for example a Second Life chat room

Students worked on their iVR environment at home, they worked together in solving some problem that appeared.

The motivating effect of the new working platform was evident in this group.

B. Creativity, Innovation

We got positive results in the field of creativity, too. This new environment, the new technology, the ability to spatially organize information inspired the students for creating something new. Even if the Purpose&Topic pair was not unusual, the solutions were creative, they inserted creative parts, creative tasks into their environments. They used the space as a real working environment where everything (any placement) is possible. Students inspired each other, too.

Most creative ideas emerged in the design and the creation of tasks. Students created trainings by using QR-codes, information mediation by using quizzes, or a team competition as a marketing tool. An environment was designed and created for a project work where the colleagues of a workplace work in teams on a project.

C. Using the New Features

At the beginning of the semester, the students had only few ideas about using the new possibilities of the new type space. They used mainly static information in static way.

After we started to talk about the new ways of using the environment, for example, the new 3rd dimension for moving in the space, students started to think on new ways, and new tasks that can use the new ways of moving, looking, and other possibilities that provide an iVR system compared to the 2D platforms. In the second month the students were working those tasks that take advantage of the iVR extra features (Fig. 3).

The tasks that students created can be classified into the following main groups:

- Working on shared documents
- Filling quizzes
- Creative drawing/placing a given object
- Project works
- Competitions
- Use of mobile devices

Every task is assigned to one or more groups, depending on its built-in features.

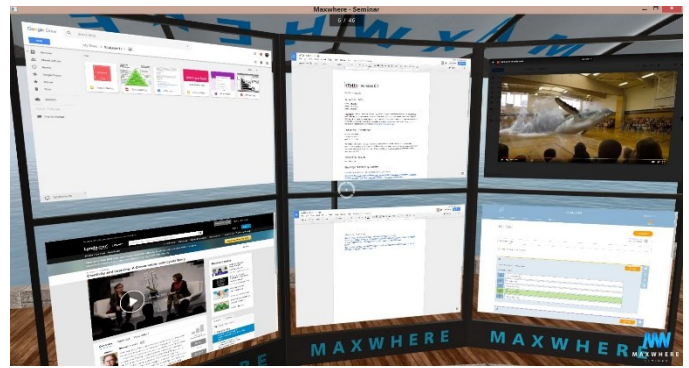


Fig. 3. Learning environment for a team work with a quiz

D. iVR in the Learning Process

It was a surprising result, that the students used the iVR only rarely for communication, collaboration and cooperation during and for the learning process. They used mainly the ‘traditional’ ways, such as the popular social network (Facebook), phone calls and two instant messaging applications (Viber and WhatsApp).

In their environments they built in ways and applications for communication and collaboration, but they did not use them in their work.

VI. EXTRA BENEFIT: FROM REAL-WORLD PROBLEMS TO ALGORITHMS

The most important benefit of this research emerged from the creativity that was inspired by that feature of the MaxWhere which make possible to organize the working and learning material in a spatially free structure. This new type of information organization unfolded unexpected correlations between the displayed pieces of information. Here we present one of them:

The students found real-world problems that had led to classical mathematical problems. In addition, students wanted to automate the problem solving, and this led them to such algorithms that they could code (or they are coding at the time of writing this article) to solve the problem in an automated way. They developed a system that is related to an inter-cognitive communication where the information transfer occurs between two cognitive beings with different cognitive capabilities – a between a human and an artificially cognitive system (see, e.g., [2], [3]).

In this section we mention two of those mathematical problems and algorithms in brief that students used for solving the real-world problems they had found.

A. Stable Matching Problem & Gale–Shapley Algorithm

In an ‘IT training’ environment designed for an IT institute, trainees have to solve a specified project, but they cannot work alone. Workers are in two different departments with different skills. The project needs the skills of both departments, so two workers have to work together, one from each department. People can choose a pair with whom they would like to work.

Students wanted to find an acceptable, automated solution for this problem.

If the program wants to find an optimal solution for creating working pairs of people with an optimal result, this problem leads to the classical Stable Matching problem (see [14]).

Its goal: Given a set of workers in dept. M (dM), and a set of workers in dept. N (dN), find a suitable matching.

A stable matching is a perfect matching with no unstable pairs. A pair is unstable if a is assigned to A and b is assigned to B , though a prefers B and b prefers A , where $a, b \in dM$, and $A, B \in dN$. (Fig. 4)

Students used the Gale–Shapley Algorithm for getting automated solutions.

In this algorithm, everyone has a preference list. And

1. Everyone chooses that person who has the highest rank on his or her list.
2. If someone has been chosen by more colleagues, he or she chooses from these people that person who has the highest rank on his or her list.
3. Those people who were not chosen, choose the next person from their preference list. And the 2nd step will be repeated.

The 3rd step will be repeated until everyone can find an acceptable alternative, or ends the preference list.

B. Travelling Salesman Problem & Ant Colony Optimization

The problem to be solved: There is an environment for training stock-brokers. The training has four parts. At the end of every part of the training there is an assessment that is performed as a competition among the participants. The final result will be the sum of the results of the four competition. The winner gets a job at a given brokerage company. The time is important in the business life, so the time is an important factor of the competition.

So there is a competition at a stock-broker training. The questions are displayed at predefined points in the VR space, and the solutions have to be written on a specified browser window. Because the time is one of the main factors, it is important for the competitors to find every piece of information in a very short way, spending with the search as short time as they can (Fig. 5).

This problem leads to the Traveling Salesmen Problem where the problem is easy, but the solution is complex.

The short description of the Traveling Salesman Problem (TSP) (see, e.g., [10]):

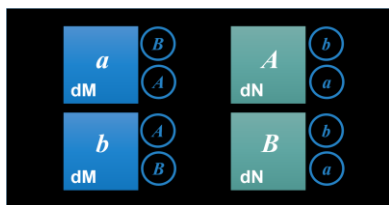


Fig. 4. Stable Matching Problem situation. Conflicts have to be solved



Fig. 5. Traveling Salesman Problem

If a travelling salesman wishes to visit exactly once each of a list of m cities and then returns to the home city, what is the least costly route that the travelling salesman can take?

Students chose the Ant Colony Optimization (ACO) metaheuristic algorithm for solving TSP. A short description of the ACO algorithm ([11]):

1. At each iteration, n ants probabilistically construct solutions to the combinatorial optimization problem under consideration, exploiting a given pheromone model.
2. (Optionally) A local search procedure is applied to the constructed solutions.
3. Before the next iteration starts, some of the solutions are used for performing a pheromone update.

The results of the algorithm will be presented for the competitors for helping them in saving time.

VII. CONCLUSIONS

In this paper we presented a teaching method applied during an IT course where we used the MaxWhere immersive virtual reality system for developing iVR environments for specified purposes. We designed and applied this method for improving creativity and inventive thinking in computer science education. During the course we tested the effectiveness of the method and examined the reactions, the activities and the progress of the students' cognitive thinking while they organize their materials in a spatial system in the iVR space.

The method that we applied for motivating our students brought positive results. Students were motivated and active during the semester and they worked a lot also at home and beyond the course requirements.

Students needed some help at the start for activating their creativity. After some weeks they felt the new way of "being", they realized the abilities of the technology, and they started to create their own environments. They collected contents and created tasks and activities in the developed environment. They provided sometimes new, innovative services that raised some problems that they wanted to solve.

The students were creative and inventive during developing their environments.

As their teachers, we were happy to see that the students are innovative, and reached an important aim because they wanted to solve the emerged problems in an active way. During their work, they wanted to identify the core of the problems, and to find an algorithm to automate every problem solving. They started to develop the computer programs based on the algorithms, and hopefully they will finalize their new environments with the designed and developed services in them. They were motivated to develop a system that is related to an inter-cognitive communication that is an important dimension of the cognitive infocommunication.

One thing was missing from the environment designs: the possibility and solutions for collaborate and communicate with their own colleagues during the process of development. This is consistent with the results of a previous research project (see [6]) where we examined the use of MaxWhere spaces teacher education. We do not say that this way for communication would be better than those channels that students use in general for their every-day communications, but we believe that students should try something else sometimes. Pointing out this, will be an important task for the educators of the next year courses.

We got that this new technology, its ability to assign spatially organized structure to pieces of information can bring positive results into educational processes – even if it can be classified as a disruptive technology. Applying it, new relationships between the elements and new correlations can be seen, it can show the reality from an alternative point of view. As a result, it can be motivating for emerging innovative ideas, and the provided possibilities may increase the creativity and develop the inventive thinking of the students. Of course we cannot say that introducing a new technology into the education can solve every problem in the effectiveness of education, but if we “speak” some common IT language with our students, it can have positive effect on the efficacy of teaching processes.

ACKNOWLEDGMENT

This research was performed in the Virtual Reality Laboratory of the Faculty of Informatics of the University of Debrecen, Hungary. We thank the equipment and the possibility to the Faculty. We thank to Professor Attila Gilányi for giving possibility to perform our VR researches.

We thank to the developers of MaxWhere especially to Professor Péter Baranyi (Széchenyi István University, Hungary) for providing us the virtual collaborative operating systems and the designed spaces for performing our research.

REFERENCES

- [1] S. C. Baker, R. K. Wentz and M. M. Woods, “Using virtual worlds in education: Second Life® as an educational tool,” *Teaching of Psychology*, vol. 36, no. 1, pp. 59–64, 2009.
- [2] P. Baranyi and A. Csapo, “Definition and synergies of cognitive infocommunications,” *Acta Polytechnica Hungarica*, vol. 9, pp. 67–83, 2012.
- [3] P. Baranyi, A. Csapo and P. Varlaki, “An overview of research trends in coginfocom,” In: *Proceedings of 18th International Conference on Intelligent Engineering Systems (INES)*. IEEE, pp. 181–186, 2014. DOI: 10.1109/INES.2014.6909365
- [4] G. Bujdosó, “Ruza breto – a smart virtual bookshelf for e-learning and electronic teaching,” In: L. Gómez Chova, A. López Martínez, I. Candel Torres (eds.), *Proceedings of 7th International Conference of Education, Research and Innovation (ICERI2014)*, Sevilla, Spain, November 17–19, 2014, International Association of Technology, Education and Development (IATED), pp. 3649–3655, 2014.
- [5] G. Bujdosó, “Virtual Reality in Teacher Training – Developing Presentations in Virtual Reality,” *Proceedings of 9th International Conference of Education, Research and Innovation (ICERI2016)*, Sevilla, Spain, November 14–16, 2016, International Association of Technology, Education and Development (IATED), pp. 4900–4905, 2016, DOI: 10.21125/iceri.2016.2170
- [6] G. Bujdosó, “Teachers’ Collaboration in Virtual Reality Environments,” In: *Proceedings of 9th International Conference on Education and New Learning Technologies (EDULEARN17)*, Barcelona, Spain, 3–5 July, 2017, International Association of Technology, Education and Development (IATED), pp. 4239–4244, 2017, DOI: 10.21125/edulearn.2017.1913.
- [7] C. M. Christensen, “The Innovator’s Dilemma – When New Technologies Cause Great Firms to Fail,” Harvard Business School Press, Boston, Massachusetts, 1997.
- [8] C. M. Christensen, “Disruptive Innovation and Catalytic Change in Higher Education,” in *Proc. Forum for the Future of Higher Education*, p. 43, 2008.
- [9] C. M. Christensen, Curtis W. Johnson, and Michael B. Horn. “Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns,” 2nd edn. New York: McGraw-Hill, 2011.
- [10] N. Christofides, Worst-case analysis of a new heuristic for the travelling salesman problem, Technical Report, Graduate School of Industrial Administration, Carnegie Mellon University, 1976.
- [11] M. Dorigo, C. Blum, “Ant colony optimization theory: A survey,” *Theoretical Computer Science*, Vol. 344, pp. 243–278, 2005.
- [12] J. Falah, S. Khan, T. Alfalah, S. F. M. Alfalah, W. Chan, D. K. Harrison; V. Charissis, „Virtual Reality medical training system for anatomy education,” *Science and Information Conference 2014, IEEE Xplore 2014*, pp. 752–758, DOI: 10.1109/SAL.2014.6918271.
- [13] P. Galambos and P. Baranyi, “VirCA as Virtual Intelligent Space for RT-Middleware,” *IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, Budapest, Hungary, 2011, pp. 140–145, 2011.
- [14] D. Gale, L.S. Shapley, College admissions and the stability of marriage. *American Mathematical Monthly*, Vol. 69, pp. 9–15, 1962.
- [15] S. Helsel, “Virtual reality and education,” *Educational Technology*, vol. 32, no. 5, pp. 38–42, 1992.
- [16] Ridong Hu, Yi-Yong Wu and Chich-Jen Shieh, “Effects of Virtual Reality Integrated Creative Thinking Instruction on Students' Creative Thinking Abilities,” *EURASIA Journal of Mathematics, Science & Technology Education*, Vol. 12, No. 3, pp. 477–486, 2016.
- [17] S. Jang, J.M. Vitale, R.W. Jyung and J.B. Black, “Direct Manipulation is Better than Passive Viewing for Learning Anatomy in a Three-Dimensional Virtual Reality Environment,” *Computers & Education*, Vol. 106, pp. 150–165, 2017. DOI: <https://doi.org/10.1016/j.compedu.2016.12.009>.
- [18] I. Makarova, R. Khabibullin, E. Belyaev and Angelina Bogateeva, “The application of virtual reality technologies in engineering education for the automotive industry,” *International Conference on Interactive Collaborative Learning (ICL) 2015, IEEE Xplore*, pp. 536–544, 2015. DOI: 10.1109/ICL.2015.7318086.
- [19] J. Psołka, “Educational Games and Virtual Reality as Disruptive Technologies,” *Educational Technology & Society*, Vol. 16, No. 2 pp. 69–80, 2013.
- [20] M. T. Sarıtaş, “Chemistry Teacher Candidates' Acceptance and Opinions about Virtual Reality Technology for Molecular Geometry,” *Educational Research and Reviews*, Vol. 10, No. 20, pp. 2745–2757, 2015.
- [21] Tsun-Ju Lin and Yu-Ju Lan, “Language Learning in Virtual Reality Environments: Past, Present, and Future,” *Educational Technology & Society*, Vol. 18, No. 4, pp. 486–497, 2015.
- [22] Xinhao Xu and Fengfeng Ke, “Designing a Virtual-Reality-Based, Gamelike Math Learning Environment,” *American Journal of Distance Education*, Vol. 30, No. 1, pp. 27–38, 2016.