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Augmented Reality in Teaching Descriptive Geometry, Engineering and Computer Graphics – Systematic Review and Results of the Russian Teachers' Experience

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ABSTRACT

The relevance and feasibility of this study are determined by the absence of serious, scientific research, as well as teaching materials, when it comes to the use of Augmented Reality (AR) in teaching students and future teachers Descriptive Geometry, Engineering and Computer Graphics (DGECG). The purpose of the study is to examine the current state of knowledge and practice of existing courses, which use the AR concept; to conduct a pedagogical experiment by teaching students how to create an information model of a building structure using the AR concept; to study the impact of the AR technology on students, lecturers, on the quality of students' design works and project presentation. The research methods used were a set of various, complementing each other methods, which can be divided into two groups: 1) theoretical: analysis of the teachers' and psychologists' works on the point of the research, analysis of methodological and educational literature; empirical: observation, statement, pedagogical experiment. The authors synthesized qualitative and quantitative AR research in the field of education. A team of students from Saint-Petersburg Mining University, Kazan (Volga region) Federal University and Financial University under the Government of the Russian Federation solved a design problem using AR and created an informational 3D-model of the structure. Existing methods of teaching students were supplemented and updated by the method of graphical presentation of the results, with due regard for AR-technologies. It has been found that at the present moment, the concept of AR has gained popularity not only among designers and planners, but also among schoolteachers, as well as among teachers at engineering universities. The absence of scientifically substantiated and proven programs and training materials for training students of DGECG using AR has also been confirmed. The necessity of further scientific research in the field of AR for DGECG has been substantiated. The article materials could prove to be useful for lecturers, schoolteachers and parents.

Keywords: universities, students, teachers, educational technology, augmented reality (AR), descriptive geometry, engineering and computer graphics (DGECG)

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Contribution of this paper to the literature

- a systematic analysis of qualitative and quantitative studies of AR-based educational courses has been proposed;
- it has been proved that AR issues in the training of DGECG students have not been sufficiently investigated in scientific and methodological literature;
- existing methods of teaching students are supplemented and updated by the method of graphical presentation of the results of creating an informational 3D-model of a building using AR-technologies.

INTRODUCTION

The Urgency of the Problem

In the modern situation of rapid design and growth of construction volumes, designers are facing new challenges. When presenting a construction project to a potential consumer, they have to deal with requirements which have never been made before. The use of modern augmented reality (AR) technologies in geometric building modeling has many advantages. Consequently, there is a need to teach students new construction design methods using AR technologies.

Along with the design, an important factor is the further presentation of the construction project to potential consumers. Augmented reality (AR) can be defined as a technology which overlays the real world with virtual objects (augmented components). Real objects are enhanced with computer-generated information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory (Augmented reality, 2019; Azuma, 1997; Azuma et al., 2001). The use of modern AR technologies provides us with a number of design tools, which can be used to complement the living, real world with digital models.

Thus, the need naturally has arisen for teaching students new design methods at construction sites using AR technologies, i.e. creating not just a project of a building being constructed in the form of drawings, mock-ups, working documentation, but a model containing all the information about the object, which can be in demand throughout the entire period of its existence - from design, then to operation, and finally to demolition or reconstruction. This model should be a full-fledged virtual copy of the building with its entire "contents" and infrastructure. Moreover, all data about the object should not only be grouped together, but be the parameters of the model, the correction of which, if necessary, entails the automatic change of the entire model. All these issues are being addressed by the new direction of design, which has relatively recently begun to be used in practice, - information modeling of buildings and structures, as well as AR-technologies.

Literature Review

As it is known, AR was used for the first time for education purposes to train Boeing's airline pilots and Air Force pilots (Caudell & Mizell, 1992). Although applications of that technology were limited primarily to an extended tracking technology, the authors of the article «Augmented Reality: An Application of Heads-Up Display Technology to Manual Manufacturing Processes» in the tutorial «Boeing Computer Services, Research and Technology» Thomas Caudell and David Mizell had already pointed out that «many near term applications are possible».

Despite the fact that:

– currently the AR-technology is used on every level of education: in school education (Billinghurst & Duenser, 2012; Chiang, Yang, & Hwang, 2014b; Kerawalla et al., 2006), at universities (Delello, McWhorter, & Camp, 2015; Ferrer-Torregrosa et al., 2015);

– its use is not as difficult as it was in the past, as it no longer requires expensive hardware and sophisticated equipment;

– according to scientists, AR is currently considered as having potential for pedagogical applications, and much is known about the advantages of using AR in education (Burton et al., 2011; Chang, Morreale, & Medicherla, 2010; Cheng & Tsai, 2013; Coffin et al., 2008; Medina, Chen, & Weghorst, 2008; Shelton & Hedley, 2003; Singhal et al., 2012; Sumadio & Rambli, 2010);

– compared to studies of other more mature education technologies (e.g., multimedia and web-based platforms), research of AR applications in education is at an early stage, and evidence of the effects of AR on teaching and learning appears to be shallow (Wu et al., 2013; Zarraonandia et al., 2013). In science education, research regarding AR-aided learning is in its infancy (Cheng & Tsai, 2013), existing research has been inconsistent, driven largely by specific technical innovations and constraints, often lacking a clear focus on establishing their efficacy in educational contexts (Lindgren & Johnson-Glenberg, 2013). Research is needed to ensure continuous enhancement of the implementation of this technology in the educational sector (Dalim et al., 2017).

The Goals and Objectives of the Study

The purpose of the study is to examine the current state of knowledge and practice of existing courses, which use the AR concept; to conduct a pedagogical experiment by teaching students how to create an information model of a building structure using the AR concept; to study the impact of the AR technology on students, on the quality of students' design works and project presentation. The main tasks were the following three:

– to discuss the effectiveness of the use of AR in teaching students DGECG, its advantages and disadvantages compared to traditional teaching method;

– to present recommendations by AR practitioners based on critical evaluation and synthesis of existing research;

– to investigate students' and teachers' attitude to this teaching model in general.

MATERIALS AND METHODS

To test the hypothesis of the study, a set of various complementing each other methods was used:

– theoretical: analysis of the teachers' and psychologists' works on the point of the research, analysis of methodological and educational literature; theoretical explanation of the possibility of introducing DGECG AR in engineering universities was given;

– empirical: observation, statement, pedagogical experiment, questioning, testing;

– experimental (stating, forming, control experiments); method of graphical representation of the results.

The experiment involved 168 first-year students and 26 teachers. The study was conducted in three stages:

– at the first stage, a theoretical analysis of existing methodological approaches in the scientific literature, dissertational works on problems, as well as theory and methodology of pedagogical research was carried out. The purpose, the methods of the research were determined, and the plan for experimental research was drawn up;

– at the second stage, experimental work was carried out, the results of the experimental work were analyzed, tested and clarified;

– at the third stage, the experimental work was completed, theoretical and practical conclusions were refined, the results obtained were summarized and systematized.

Progress and Description of the Experiment

Systematic review of the literature

Before the experiment on teaching students, a systematic review of the literature on the teaching methods used in educational institutions based on AR was conducted. More than 120 scientific articles were selected for analysis. When conducting a literature analysis, the following factors were considered: category of the educational institution and student, year of publication, academic discipline, AR technologies; the advantages and problems of using AR in educational institutions were considered.

The formation of experimental groups of students. Setting a task

In the course of the experiment, 168 first-year students were given the task to create an information model of a building.

The work was divided between three groups of students. The first group developed the building project in the traditional ways, the second group - using modern information technologies, the third group - consumer experts (customers) – estimated and compared the time spent, efforts, the results obtained and the perception of the final project. Existing methods of teaching students were supplemented and updated by the methods of graphical presentation of the results with due regard for AR-technologies.

Stages of the students' work on creating an information model of the building

1. At the first stage, primary design elements were developed that corresponded to both construction products (floor slabs, doors, windows, etc.), and equipment elements (heating and lighting devices, elevators, etc.)

and everything that is directly related to the building, but is produced outside the construction site and during the construction of the object is not divided into parts.

2. The second stage was the modeling of everything that is created at the construction site. These are foundations, walls, roofs, curtain walls, etc. Thus, information modeling of a building initially implies having the understanding of how to erect this building, how to equip it and how to live and work in it. The division into stages (first and second) when creating the information model of the structure is not mandatory – for instance, it's possible to insert windows into the simulated objects, and then change them, and the already changed windows will appear in the project.

3. At the third stage, a virtual building model was created.

Problem Status

– Currently, AR-technologies are used at all levels of education: at schools, at universities.

– Using AR at our time is not as difficult as it was in the past, since it no longer requires expensive and complex equipment.

– AR is currently considered to have potential for pedagogical application and much is known about the benefits of AR in education

– There is not much evidence of the impact of AR on teaching and learning. In the field of science education, research in the field of AR-enhanced learning is in its infancy.

– Existing studies are fragmented, mainly due to specific technical innovations and limitations, often do not have a clear focus on establishing their effectiveness in the educational context, and further research is needed to ensure continuous improvement and more efficient introduction of this technology in the educational sector.

RESULTS

A Systematic Analysis of Studies of AR-Based Educational Courses

Tables 1-5 present some research conducted on AR in different fields of education. The analysis includes examples of how the AR technology was implemented in the respective fields of education, namely, Medicine, Chemistry, Mathematics, Physics, Biology, Astronomy and History. This research was conducted in order to evaluate the potential of AR in education.

Table 1. AR in different fields of preschool and school education

№	Year	Academic discipline	Authors	Article title
1	2003	Mathematics and geometry	H. Kaufmann & D. Schmalstieg (2003)	Mathematics and geometry education with collaborative augmented reality
2	2006	Primary school science	L. Kerawalla, R. Luckin, S. Seljeflot & A. Woolard (2006)	«Making it real»: exploring the potential of augmented reality for teaching primary school science
3	2006	Chemistry	Y.-C. Chen (2006)	A study of comparing the use of augmented reality and physical models in chemistry education
4	2008	Physics	S.A. Sotiriou & F.X. Bogner (2008)	Visualizing the invisible: Augmented reality as an innovative science education scheme
5	2009		C.J. Dede (2009)	Immersive interfaces for engagement and learning
6	2010	Building	L. Simeone & S. Iaconesi (2010)	Toys++ AR embodied agents as tools to learn by building
7	2010	Environment	W. Chang, Q. Tan & F.W. Tao (2010)	Multi-object-oriented augmented reality for location-based adaptive mobile learning
8	2010	Anatomy (digestive and circulatory systems)	D. Pérez-López, M. Contero & M. Alcãiz (2010)	Collaborative development of an augmented reality application for digestive and circulatory systems teaching
9	2011	10-17 ages	N.A.M. El Sayed, H.H. Zayed & M.I. Sharawy (2011)	ARSC: Augmented reality student card
10	2011	Conservation of fish in Taiwan	H.-C.K. Lin, M.-C. Hsieh, C.-H. Wang, Z.-Y. Sie & S.-H. Chang (2011)	Establishment and usability evaluation of an interactive AR learning system on conservation of fish
11	2011	Physics	J. Gu, N. Li & H.B.L. Duh (2011)	A remote mobile collaborative AR system for learning in physics
12	2012	Elementary school	C.-M. Chen & Y.-N. Tsai (2012)	Interactive augmented reality system for enhancing library instruction in elementary schools

Table 1 (continued). AR in different fields of preschool and school education

№	Year	Academic discipline	Authors	Article title
13	2012	Science museum	S.A. Yoon, K. Elinich, J. Wang, C. Steinmeier & S. Tucker (2012)	Using augmented reality and knowledge-building scaffolds to improve learning in a science museum
14	2012	Ecosystems	K.-F. Hsiao, N.-S. Chen & S.-Y. Huang (2012)	Learning while exercising for science education in augmented reality among adolescents
15	2012	Astronomy	G.-J. Hwang, C.-C. Tsai, H.-C. Chu, K. Kinshuk & C.-Y. Chen (2012)	A context-aware ubiquitous learning approach to conducting scientific inquiry activities in a science park
16	2012	Insect (butterfly) ecology	W. Tarng & K.-L. Ou (2012)	A study of campus butterfly ecology learning system based on augmented reality and mobile learning
17	2012	Secondary schools	M. Davidsson, D. Johansson & K. Lindwall (2012)	Exploring the use of augmented reality to support science education in secondary schools
18	2012	Geometric shapes	T.G. Kirner, F.M. Reis, V. & C. Kirner (2012)	Development of an interactive book with Augmented Reality for teaching and learning geometric shapes
19	2013	Art	A. Di Serio, M.B. Ibanez & C.D. Kloos (2013)	Impact of an augmented reality system on students' motivation for a visual art course.
20	2013	Urban middle school	D. Bressler & A. Bodzin (2013)	A mixed methods assessment of students' flow experiences during a mobile augmented reality science game
21	2013	Pond environment	A.M. Kamarainen, S. Metcalf, T. Grotzer, A. Browne, D. Mazzuca, M.S. Tutwiler & K. Dede (2013)	EcoMOBILE: Integrating augmented reality and probe ware with environmental education field trips
22	2013	Physics	Cai, Chiang & Wang (2013)	Using the augmented reality 3D technique for a convex imaging experiment in a physics course
23	2014	Astronomy	J. Zhang, Y.-T. Sung, H.-T. Hou, & K.-E. Chang (2014)	The development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction
24	2014	Art	K.-E. Chang, C.-T. Chang, H.-T. Hou, Y.-T. Sung, H.-L. Chao, & C.-M. Lee (2014)	Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum
25	2014	Natural science	T.H.C. Chiang, S.J.H. Yang & G. Hwang (2014a)	An Augmented Reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities
26	2014	Chemistry	S. Cai, X. Wang & F.K. Chiang (2014)	A case study of augmented reality simulation system application in a chemistry course
27	2015	Young children	J. Han, M. Jo, E. Hyun & H.-J. So (2015)	Examining young children's perception toward augmented reality-infused dramatic play
28	2015	Marine education	S.-J. Lu & Y.-C. Liu (2015)	Integrating augmented reality technology to enhance children's learning in marine education
29	2015	Primary education	J.A. Munoz-Cristobal, I.M. Jorrin-Abellan, J.I. Asensio-Perez, A. Martinez-Mones, L.P. Prieto & Y. Dimitriadis (2015)	Supporting teacher orchestration in ubiquitous learning environments: A study in primary education
30	2015	Solid geometry	H.-C.K. Lin, M.-C. Chen, & C.-K. Chang (2015)	Assessing the effectiveness of learning solid geometry by using an augmented reality-assisted learning system
31	2016	Reading	K.-H. Cheng & C.-C. Tsai (2016)	The interaction of child–parent shared reading with an augmented reality (AR) picture book and parents' conceptions of AR learning
32	2016	Art	Y.Li.H. Huang & R. Fong (2016)	Using augmented reality in early art education: A case study in Hong Kong kindergarten. Early Child Development and Care
33	2017	Software editing course	Y.H. Wang (2017)	Using augmented reality to support a software editing course for college students
34	2017	Writing	Y.H. Wang (2017)	Exploring the Effectiveness of Integrating Augmented Reality-Based Materials to Support Writing Activities
35	2017	English	T.C. Hsu (2017)	Learning English with augmented reality: Do learning styles matter?
36	2017	Geometric objects and measuring volume	E.T. Gün & B. Atasoy (2017)	The effects of augmented reality on elementary school students' spatial ability and academic achievement
37	2017	Pedestrian navigation	J. Joo-Nagata, F.M. Abad, J.G.B. Giner & F.J. García-Peñalvo (2017)	Augmented reality and pedestrian navigation through its implementation in m-learning and e-learning: Evaluation of an educational program in Chile
38	2017	English alphabet	A.H. Safar, A.A. Al-Jafar & Z.H. Al-Yousefi (2017)	The effectiveness of using augmented reality apps in teaching the English alphabet to kindergarten children: A case study in the State of Kuwait
39	2017	5-6 ages	R. Yilmaz & S. Kucuk & Y. Goktas (2017)	Are augmented reality picture books magic or real for preschool children aged five to six?

Table 2. AR in different fields of university education

№	Year	Academic discipline	Authors	Article title
1	2002	Astronomy	B.E. Shelton & N.R. Hedley (2002)	Using augmented reality for teaching earth-sun relationship to undergraduate geography students
2	2006	Guitar playing	Y. Motokawa, & H. Saito (2006)	Support system for guitar playing using augmented reality display
3	2007	Environmental engineering education	K.D. Squire, & E. Klopfer (2007)	Augmented reality simulations on handheld computers
4	2007	Environmental engineering education	K.D. Squire, & M. Jan (2007)	Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers
5	2008	Biochemistry	E. Medina, Y.-C. Chen, & S. Weghorst (2008)	Understanding biochemistry with augmented reality
6	2009	Magnetism	S. Matsutomo, T. Miyauchi, Noguchi, & S.H. Yamashita (2009)	Realtime visualization system of magnetic field utilizing augmented reality technology for education
7	2010	Live Solar System	A.K. Sin & B.Z. Halimah (2010)	Live Solar System (LSS): Evaluation of an Augmented Reality book-based educational tool
8	2010	Mechanical engineering	J. Martín-Gutiérrez, , J. L. Saorín, M. Contero, M. Alcañiz, D.C. Pérez-López, & M. Ortega (2010)	Design and validation of an augmented book for spatial abilities development in engineering students
9	2011	Anthropology	L. Simeone & S. Iaconesi (2011)	Anthropological conversations: Augmented reality enhanced artifacts to foster education in cultural anthropology
10	2011	English	Y.-J. Chang, C.-H. Chen, W.-T. Huang, & W. Huang (2011)	Investigating students' perceived satisfaction, behavioral intention, and effectiveness of english learning using augmented reality
11	2012	Chemistry	S. Singhal, S. Bagga, P. Goyal & V. Saxena (2012)	Augmented chemistry: interactive education system
12	2012	Anatomy	T. Blum, V. Kleeberger, C. Bichlmeier & N. Navab (2012)	Mirracle: an augmented reality magic mirror system for anatomy education
13	2012	Physical education (PE)	K.-F. Hsiao (2012)	Using augmented reality for students healthcase of combining educational learning with standard fitness
14	2012	engineering labs	S. Odeh, S.A. Shanab, M. Anabtawi & R. Hodrob (2012)	Remote augmented reality engineering labs
15	2012	Chemistry	S. Singhal, S. Bagga, P. Goyal, & V. Saxena (2012)	Augmented chemistry: interactive education system.
16	2014	Construction	S. Kiryakidi (2014)	Augmented reality and the prospects for its use in the construction industry
17	2014	Math	P. Sommerauer, & O. Müller (2014)	Augmented reality in informal learning environments: A field experiment in a mathematics exhibition
18	2014	Electromagnetism	M.B. Ibáñez, A. Di Serio, D. Villarán & C.D. Kloos (2014)	Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness
19	2015	Industrial maintenance and assembly	N. Gavish, T. Gutierrez, S. Webel, J. Rodríguez, M. Peveri, U. Bockholt & F. Tecchia (2015)	Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks
20	2015	Anatomy	J. Ferrer-Torregrosa, J. Torralba, M.A. Jimenez, S. García & J.M. Barcia (2015)	ARBOOK: Development and assessment of a tool based on augmented reality for Anatomy
21	2015	Technical creative design course	X. Wei, D. Weng, Y. Liu & Y. Wang (2015)	Teaching based on augmented reality for a technical creative design course
22	2016	Dental morphology	M. Juan (2016)	M.A Juan mobile augmented reality system for the learning of dental morphology
23	2017	Math	P. Salinas & R. Pulido (2017)	Understanding the conics through augmented reality
24	2018	Chemistry	S. Yang, B. Mei & X. Yue (2018)	Mobile augmented reality assisted chemical education: insights from elements 4D

Table 3. AR in special directions of education

№	Year	Academic discipline	Authors	Article title
1	2009	Science education for learners with physical disabilities	T.N. Arvanitis, A. Petrou, J.F. Knight, S. Savas, S. Sotiriou, M. Gargalakos & E. Gialouri (2009)	Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities
2	2009	Musical system for children with cerebral palsy rehabilitation	A.G.D. Corrêa, I.K. Ficheman, M. Nascimento & R. Lopes (2009)	Computer assisted music therapy: a case study of an augmented reality musical system for children with cerebral palsy rehabilitation
3	2010	Book for deaf students	N.M.M. Zainuddin, H.Z. Badioze Zaman & A. Ahmad (2010)	A participatory design in developing prototype an Augmented Reality book for deaf students
4	2015	ICT for the elderly	R. Saracchini, , C. Catalina & L. Bordoni (2015)	A mobile augmented reality assistive technology for the elderly
5	2015	Physical activities for children with developmental disabilities	C.Y. Lin & Y.M. Chang (2015)	Interactive augmented reality using Scratch 2.0 to improve physical activities for children with developmental disabilities
6	2016	For students with intellectual disabilities and autism	D.D. McMahon, D.F. Cihak, R.E. Wright & S.M. Bell (2016)	Augmented reality for teaching science vocabulary to postsecondary education students with intellectual disabilities and autism

Table 4. Reviews of AR applications in education

№	Year	Authors	Article title
1	2009	M. Dunleavy, C. Dede & R. Mitchell (2009)	Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning
2	2009	D. Yu, J.S. Jin, S. Luo, W. Lai & Q. Huang (2009)	A useful visualization technique: A literature review for augmented reality and its application, limitation & future direction
3	2010	R.S. Davies, S.L. Howell & J.A. Petrie (2010)	A review of trends in distance education scholarship at research universities in North America,
4	2011	S.C. Bronack (2011)	The role of immersive media in online education
5	2011	G.-J. Hwang & C.-C. Tsai (2011)	Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010
6	2012	W.-H. Wu, Y.-C.J. Wu, C.-Y. Chen, H.-Y. Kao, C.-H. Lin & S.-H. Huang (2012)	Review of trends from mobile learning studies: A meta-analysis
7	2012	I. Radu (2012)	Why should my students use AR? A comparative review of the educational impacts of augmented-reality
8	2013	H.-K. Wu, S. W.-Y., Lee, H.-Y. Chang & J.-C. Liang (2013)	Current status, opportunities and challenges of augmented reality in education
9	2013	P.H.E. Liu & M.K. Tsai (2013)	Using augmented-reality-based mobile learning material in EFL English composition: An exploratory case study
10	2014	M. Antonioli, C. Blake & K. Sparks (2014)	Augmented reality applications in education
11	2014	J. Bacca, S. Baldiris, R. Fabregat, & S. Graf (2014)	Augmented reality trends in education: A systematic review of research and applications
12	2014	M.E.C. Santos, A. Chen, , T. Taketomi, G. Yamamoto, J. Miyazaki & H. Kato (2014)	Augmented reality learning experiences: Survey of prototype design and evaluation
13	2014	I. Radu (2014)	Augmented reality in education: a meta-review and cross-media analysis
14	2014	J.M. Martin-Gutiérrez & M.D.M. Fernandez (2014)	Applying augmented reality in engineering education to improve academic performance & student motivation
15	2015	Y.-L. Chang, H.-T. Hou, C.-Y. Pan, Y.-T. Sung & K.-E. Chang (2015)	Apply an augmented reality in a mobile guidance to increase sense of place for heritage places
16	2015	N.F. Saidin, N.D. Abd Halim & N.N Yahaya (2015)	A Review of Research on Augmented Reality in Education: Advantages and Applications International Education Studies
17	2015	J.A. Delello, R.R. McWhorter & K.M. Camp (2015)	Integrating augmented reality in higher education: a multidisciplinary study of student perceptions
18	2016	G. Akçayır & M. Akçayır (2016)	Research trends in social network sites' educational use
19	2016	Tekederea, H. & Göke, H. (2016)	Examining the Effectiveness of Augmented Reality Applications in Education: A Meta-Analysis
20	2017	C.S.C. Dalim, H. Kolivand, H. Kadhim, M.S. Sunar & M. Billinghurst (2017)	Factors Influencing the Acceptance of Augmented Reality in Education
21	2017	J. Li, E. Spek, L. Feijs, F. Wang & J. Hu (2017)	Augmented Reality Games for Learning: A Literature Review
22	2017	Y.H. Hung, C.H. Chen & S.W. Huang (2017)	Applying augmented reality to enhance learning: A study of different teaching materials
23	2017	M. Akçayır & G. Akçayır (2017)	Advantages and challenges associated with augmented reality for education: A systematic review of the literature.
24	2018	J. Garzón, J. Pavón & S. Baldiris (2018)	Systematic review and meta-analysis of augmented reality in educational settings
25	2018	N. Pellas, P. Fotaris, I. Kazanidis & D. Wells (2018)	Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning
26	2018	M. Sırakaya & D. Alsancak Sırakaya (2018)	Trends in Educational Augmented Reality Studies: A Systematic Review
27	2018	R.M. Yilmaz (2018)	Augmented Reality Trends in Education between 2016 and 2017 Years, State of the Art Virtual Reality and Augmented Reality Knowhow

Table 5. AR in Descriptive Geometry

№	Year	Authors	Article title
1	2005	H. Kaufmann, K. Steinbügl, A. Dünser & J. Glück (2005)	General training of spatial abilities by geometry education in Augmented Reality
2	2006	H. Kaufmann (2006)	The potential of augmented reality in dynamic geometry education.
3	2011	H. Chen, K. Feng, C. Mo, S. Cheng, Z. Guo & Y. Huang (2011)	Application of Augmented Reality in Engineering Graphics education
4	2013	J. Martin-Gutiérrez, M. García-Domínguez, C. Roca-González, A. Sanjuán-HernanPérez & C. Mato-Carrodeguas (2013)	Comparative analysis between training tools in spatial skills for Engineering Graphics students based in Virtual Reality, Augmented Reality and PDF3D Technologies
5	2014	Z. Veide, V. Stroževa & M. Dobelis (2014)	Application of Augmented Reality for teaching Descriptive Geometry and Engineering Graphics course to first-year students
6	2015	N. Argelia Aguilera González (2015)	How to include Augmented Reality in Descriptive Geometry Teaching
7	2016	E. Gutiérrez de Ravé, F. Jiménez-Hornero, A. Ariza Villaverde & J.Taguas-Ruiz (2016)	Mobile augmented reality system applies to Descriptive Geometry learning
8	2016	J.deF. Pires, L.D. Vecchia, & A.A.daS Borda (2016)	Transiting between representation technologies and teaching/learning Descriptive Geometry: reflections in an architectural context
9	2017	A. Cascales-Martínez, M.J. Martínez-Segura, D. Pérez-López & M. Contero (2017)	Using an augmented reality enhanced tabletop system to promote learning of mathematics: A case study with students with special educational needs

Experiment

After reviewing the problem being studied - teaching students with the help of the AR technology – an experiment was conducted to introduce this technology to the educational process (Tretyakova & Merkulova, 2017; Tretyakova et. al., 2018; Tretyakova, Merkulova, & Voronina, 2018). In the course of this experiment, 168 first-year students were given the task to create an informational model of a building.

The work was divided between three groups of students. The first group developed the building project in the traditional ways, the second group - using modern information technologies, the third group - consumer experts (customers) – estimated and compared the time spent, efforts, the results obtained and the perception of the final project. Existing methods of teaching students were supplemented and updated by the methods of graphical presentation of the results with due regard for AR-technologies.

Stages of the Students' Work on Creating an Information Model of the Building

1. At the first stage, primary design elements were developed that corresponded to both construction products (floor slabs, doors, windows, etc.), and equipment elements (heating and lighting devices, elevators, etc.) and everything that is directly related to the building, but is produced outside the construction site and during the construction of the object is not divided into parts.
2. The second stage was the modeling of everything that is created at the construction site. These are foundations, walls, roofs, curtain walls, etc. Thus, information modeling of a building initially implies having the understanding of how to erect this building, how to equip it and how to live and work in it. The division into stages (first and second) when creating the information model of the structure is not mandatory - for instance, it's possible to insert windows into the simulated objects, and then change them, and the already changed windows will appear in the project.
3. At the third stage, a virtual building model was created.

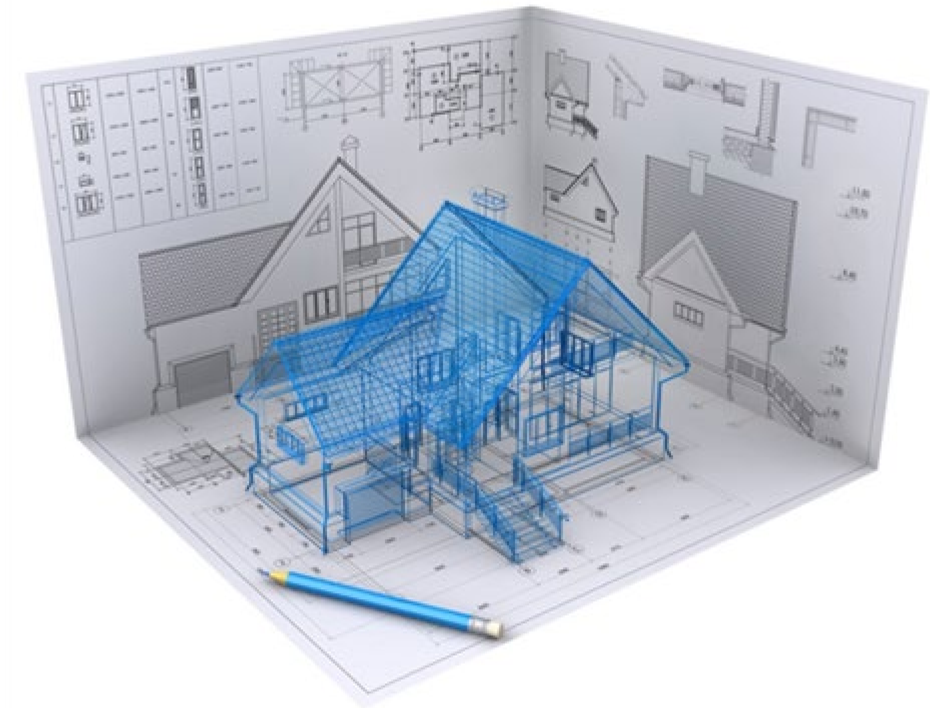

Figure 1. Creation of an informational model of a building

Using new technologies and uniting all the stages of project development allows for the reduction of time spent on the project thanks to the interconnection of the previously separate stages. The work of different specialists such as an architect, planner, communication engineer or designer is now constantly linked.

As a visualisation AR-tool a software package can be used; such a package would consist of the following elements:

1. An application for portable devices such as a phone, tablet, laptop or PC. To run this application the device must have a camera, internet access and the appropriate OS and hardware.
2. Software allowing work with databases and QR-codes (adding and removing objects, QR-code generation, marker printing). It must be noted that any free service can be used for code generation. A QR-code is a code containing an encrypted identifier which corresponds to a specific operation.

This way, an informational model of a building has been created which allows the viewer to 'get inside the structure' and examine all its elements in detail (**Figure 2**).

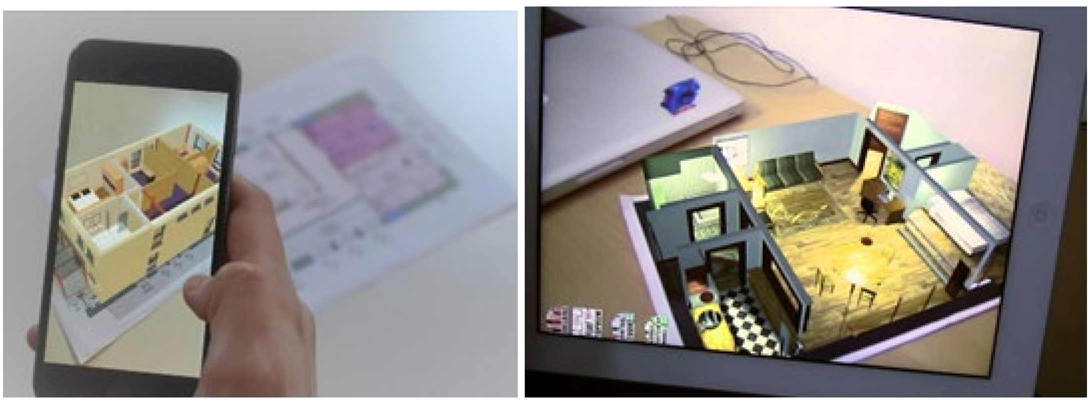

Figure 2. Informational model of a building

To carry out a similar project using traditional methods would be much more time- and energy-consuming. What's more, the final result would be much less informative for the consumers who do not possess even basic knowledge of building design; all the conventional signs and markers seen in the model as well as the importance of constructive elements have to be understandable for the end user.

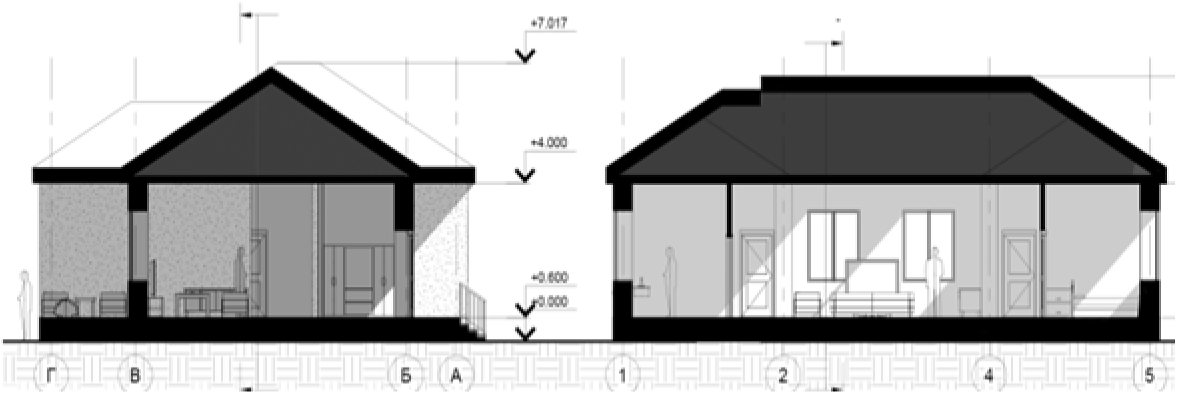

Figure 3. Project created using traditional methods

DISCUSSION

The third group of students, acting as customers, estimated the perception of the project. In their opinion, the informational model of the building created with the help of modern computer technologies allows for a fuller view of the structure. What's more, from the consumer's point of view such a presentation is more graphic, as it's usually quite challenging for them to understand details of the drawing.

The design process always depends on the interests of two groups of people: planners and consumers. Each group aspires to have their requirements met, which can sometimes cause controversy. And the project authors inevitably face the problem of choosing the final variant of the design.

Having created a few 3D models using AR-software, it's possible to show the possible options to the customer and begin negotiations at the very first meeting. Several cards with bindings can make solving technical problem much easier and quicken the discussion, as AR allows for an immediate transformation of an idea into a visual model. At the moment it is only a prototype on the building market, but it will give a company the chance to stand out while keeping its expenses to a minimum. It is also possible to use AR at the construction site itself to specify some moments concerning the position of the building on the plot. Designing the plot at the initial stage is made significantly less difficult by the clearness of the work and also the ability to do it online (Augmented Reality: Mobile Architectural Applications of the Future, 2015).

The AR technology gives designers the opportunity to follow the stages of the building project and compare the real object with its model. This way, people who are unfamiliar with the building sphere can without much effort control building erection.

AR is absolutely irreplaceable for finishing work as its use reduces not only the amount of time spent on building the structure, but also the probability of builders making a mistake; it also prevents arguments arising between the customer and the developer because of misunderstanding.

The main advantage of AR is the absence of the necessity to use any additional resources. For example, compared to VR-objects (which require a significant amount of additional hardware such as VR-glasses or helmets to be shown), AR-drawings can be seen on the screen of a usual phone or tablet, now owned by almost everyone.

CONCLUSION

The team of students successfully carried out the task of designing a building using AR and created an informational model of this building. Based on the research conducted by the students, their teachers gave recommendations concerning their further education. However, despite the obviousness of the need to teach AR and its application to designing buildings and structures to the new generation of students, this research has shown that there is still no well-tested curriculum, as well as teaching materials, when it comes to the use of AR.

It's worth saying that teachers do not have to base their classes exclusively on AR technologies, but the latter have to become part of the lesson, providing additional visual support.

Besides, learning a subject takes more than simply acquiring theoretical knowledge. It's impossible to limit students' work to attending lectures and checking graphic materials. Students, especially those who want to become technical specialists, have to be taught practical skills and get professional experience. Sometimes acquiring such skills at university is not feasible, therefore laboratories equipped with AR hard- and software can provide future graduates with at least visual skills.

The main advantage of AR is that it visualizes difficult to imagine objects by turning them into 3D models, which facilitates students' understanding of abstract and complex information. Its users can choose the color, transparency, angle etc. This approach is especially useful for improving students' abstract thinking and for people who work on transforming theoretical material into real projects.

Despite being actively used in many spheres of modern life, AR as a tool of modernizing education is still a matter open for discussion.

Which leads to the conclusion that it is necessary to:

- create a theoretical base in teaching DGECG with the help of AR and assessing students' progress.
- carry out further research studying various aspects of practical realization of long-term, well-tested programs and teaching materials in teaching AR to DGECG students.

RECOMMENDATIONS

This article could be found useful by teachers of technical subjects who aspire to increases their students' understanding of the information they are given in class.

We see the presented model of facilitating students' learning as a perspective direction which should be further developed and introduced to the curriculums of various educational institutions.

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