Shih, JL. et al. (Eds.) (2023). Proceedings of the 31st International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Using of Augmented Reality Technology in the Learning Process of Calculus2 for Higher Education Students

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Abstract: This paper presents the use of augmented reality techniques to enhance learning experience of studying Calculus2. One of the main problems in learning Calculus is the lack of spatial recognition in objects, especially 3-dimensional objects. To improve students' understanding and immersive experience, Augmented Reality (AR) is applied to overlay 3D objects onto the student's view of the physical world. The chosen 3-dimensional objects include sphere, hyperbolic paraboloid, elliptic paraboloid, paraboloid, cone, ellipsoid, cylindrical, elliptic hyperboloid of one sheet, and elliptic hyperboloid of two sheet. From testing, 30 students found the augmented reality technology effectively helps in learning shapes and calculation for volume and surface area.

Keywords: Augmented Reality Technology, Geogebra 3D, Geometry, Calculus2

1. Introduction

Information and communication technology has invented and developed to provide new mediums for communication such as 3D illustration, video and interactive graphical object. These new technologies help to improve understanding more than just words communicating that can be ambiguous. In education, a textbook is the main teaching materials to provide structural and comprehensive content, reference material, and visual aids. Textbooks generally include diagrams, illustrations, charts, graphs, and other visual aids that help students visualize and understand complex concepts. Illustrations of real-world objects give students a rough concept of thing that is mentioned in a descriptive content. However, illustrations have major limitation as two-dimensional presentation (2D). Furthermore, the illustration is a still image which does not instigate sufficient interest of students (McQuail, 2005). In the higher education such as engineer and biology, the complexity of the content requires students to clearly understand the content and visualize the complex structure of things to learn further in the subject. As one of the mandatory subjects, Calculus2 is to study and analyze three-dimensional objects, particularly when it comes to finding volumes, surface areas, and other properties of such objects. Students may confuse or not fully understand 3D shapes such as hyperbolic paraboloid, elliptic paraboloid, ellipsoid, cylindrical, elliptic hyperboloid of one sheet, and elliptic hyperboloid of two sheet.

In this paper, we present the use of augmented reality to visualize 3D shapes for students who learn in Calculus2. This research raises the question whether teaching Calculus2 with 3D images will help to improve interest and understanding for students or not. The scope of this research is 3D shapes of sphere, hyperbolic paraboloid, elliptic paraboloid, paraboloid, cone, ellipsoid, cylindrical, elliptic hyperboloid of one sheet, elliptic hyperboloid of 2 sheet. The applied augmented reality is developed as a mobile application (android operating system only) and use in a classroom of 30 students in a subject of Calculus2.

2. Analysis of recent research and publications

Education 4.0 has modern digital technologies such as augmented reality (AR), virtual reality (VR), and 3D printers applied to different levels of the teaching and learning process. Each of these technologies show a positive effect on learning. The interest in these technologies is growing among teachers and learners.

Augmented reality (AR) is a technology that can combine the real world with the virtual world through a mobile smart device in conjunction with various application software to make the image seen on the screen. This can be an object with a 3D perspective or a 360-degree panoramic view. Users at different levels are increasingly willing to interact with subjects in cyberspace, which can lead to the expansion of educational activities, improving existing and new organizational forms, types and methods of teaching, improving student interaction and educational space (Monfared et al., 2022). AR is expecting to change education and displace the game as an educational technology (Ashley-Welbeck & Vlachopoulos, 2020). Features of the use of AR technology, its impact and importance in the educational process of various specialties and fields have been discussed in national and international academic articles (Akçayır et al., 2016; Dinis et al., 2018; Huttar & BrintzenhofeSzoc, 2020; Frolli et al., 2021; Yusuf & Ichsan, 2021; Trust et al., 2021; Volynets, 2021)

Researchers believe AR will make teaching and learning more interesting. It facilitates the learning process and use frequently in an e-learning system. However, there is a remark as it may reduce direct dialogue between teachers and students. Therefore, the use of e-learning technology in education should be used in short-term classes or as a simulation device (Murodillayevich, Eshpulatovich, & Pardaboyevich, 2019). Moreover, AR is a popular technology in mathematics education (Melnyk, Nefedova, & Zadyrey, 2018; Osypova, & Tatochenko, 2021). It is noted that while studying mathematics, students found it is difficult to follow and lost interest due to the complexity of the subject. The use of AR technology in teaching can help students learn some concepts or theories that are difficult to understand in the classroom by creating instructional materials with appropriate 3D models to develop students' spatial and imagination abilities (Gargrish et ai., 2021). This assists to deepen the understanding of processes, properties, theorem proofs, etc. In addition, AR can radically change the way subjects are taught by emphasizing student participation and interaction with learning activities through practice (Melnyk, Nefedova, & Zadyrey, 2018). Some articles (Ancochea & Cárdenas, 2020; Babkin et al., 2021; Osypova & Tatochenko, 2021) applied GeoGebra 3D Graphing Calculator, a mathematical aid program, for solving 3D mathematical problems. The provided graphing 3D functions and 3D geometry surfaces is highly efficient with augmented reality (AR) technology in the study of geometry. The article (Babkin et al., 2021) discusses cross-platform products that should be used to develop AR technologies including Unreal Development, Kit, Unity, Godot, Engine, Cocos2D, MonoGame, Unreal Engine, Marmalade, and the capabilities of a new AR software development kit (or SDK) called ARCore that will be brought to Android smartphones (Wikitude, Vuforia, Kudan, Maxst, Xzimg, NyARToolkit, Metaio SDK) (Vakaliuk & Pochtoviuk, 2021).

3. Research design

This research is a research and development (R&D). Research objective is to develop a learning assistant tool for Calculus2 subject using augmented reality (AR) technology for representing three-dimensional space with various shapes including hyperbolic paraboloid, elliptic paraboloid, ellipsoid, cylindrical, elliptic hyperboloid of one sheet, and elliptic hyperboloid of two sheet. Procedures in this research applied several stages as (1) observing research location, (2) creating learning materials, (3) expert validation, (4) testing into small group, (5) setting up into large group (field test).

To develop the learning assistant tool for Calculus2 subject, we chose GeoGebra 3D with AR (GeoGebra Augmented Reality) extension as the development platform to construct the three-dimensional space with various shapes. The image processing application is

performed using the Augment application. This application is a mobile application downloadable on android OS.

For evaluation, there are three experts who are tasked to examine learning materials, namely two experts in mathematics and computer technology. The issues for evaluating the quality of augmented reality (AR) learning materials include graphics and design, fast access to information, animations, clarity and technicality. After the expert commented and consented the tool, adjustments were made according to the instructions, and the tool was brought to trial (Pilot) with thirty students. The learning materials and tools were assessed with the developed questionnaire and improved again before being experimented in a large group (for field test). This research collected both qualitative and quantitative data. The qualitative data such as answers, reviews and suggestions are obtained from interviews and the quantitative data consisted of a quality check form of experts and opinions of students from questionnaires. The data was analyzed using descriptive analysis consisting of frequency, percentage, mean and standard deviation.

Consider examples of the use of GeoGebra Augmented Reality to solve problems of the course “Calculus2” on the topics “Application of the integral” (functions of one and more variables) and “Area of definition of the function of several variables”. Geogebra Mathematical Package can also be used to calculate geometric quantities (areas, volumes) and physical quantities (masses, coordinates of the center of mass, work, pressure forces). However, we focus on the ability of the GeoGebra Augmented Reality tool to complement physical reality with digital model-objects that are specified in the task condition. In solving such problems, the greatest difficulties arise when performing geometric constructions and visualization of mathematical objects. Qualitatively performed geometric constructions are one of the conditions for the correct solution of the problem.

For usage, students initially open up GeoGebra 3D Calculator application and create any 3D solid model (see Figure 1) to create a 3D Graphics in an augmented reality application. Next, they are asked to press the AR button (lower right within 3D Graphics pane). Students thus will see environment on the screen. After following the usage instruction, the tool will virtually place the object you were viewing within your environment. Students can also use fingers to reposition the objects and allow to use the touch screen to change the size and color of the object.

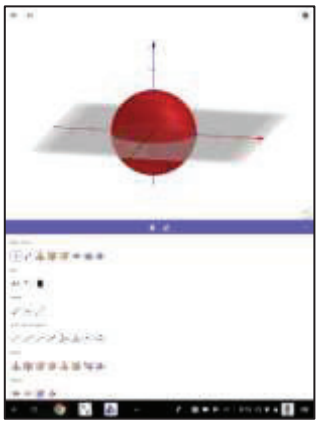

Figure 1. Demonstration of 3D creating sphere shape.

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Figure 2. Demonstration of triangulated and square appear over the flat surface.

From the example given in Figure 3, the calculation of the area of the part of the paraboloid is $z = x^2 + y^2$. Students can see the visualization of the mathematical object given by the condition of the problem. The volume of the body of rotation can be calculated using the tool “Integral”.

Figure 3. Demonstration of 3D creating paraboloid shape.

4. Conclusions

The usage of augmented reality technologies promotes visualization in the educational process, the formation of cognitive interest and motivation of students. It has significant methodological potential, which should be used in the study of various mathematical disciplines, particularly in the study of mathematical analysis. The use of such technologies can probably have a great effect, but the constant use in the standard practical training of 90 minutes leads to a significant violation of the program. However, the use of augmented reality technologies is the most adequate as an additional means of visualizing calculus2 objects in solving problems.

The results of student surveys and trainings confirm the positive impact of augmented reality (AR) technologies on the learning process and the quality of learning outcomes. From interview results, a significant number of higher education students note that augmented reality (AR) technology helps to better understand theoretical material and enhances the visual component. Some students also mentioned that it gives more immersive experience than traditional lecture and self-reading. Furthermore, it keeps students’ interest in class and focus on studying as using the tool is more practical and require students’ interactivity.

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