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Research Article

ENGAGING PRE-SERVICE MATHEMATICS TEACHER IN USING AUGMENTED REALITY TECHNOLOGY: THE CASE OF "3D CALCULATOR" APP

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ABSTRACT

Over the past ten years, along with the proliferation of mobile devices, augmented reality technology has been increasingly widely used in many fields. In particular, many studies have shown its benefits for education. In this context, the article illustrates this new technology update in training pre-service mathematics teachers at Ho Chi Minh City University of Education. Specifically, 62 third-year students were trained to use the "3D Calculator" *application (which just appeared in July 2019) through performing tasks such as* "Create a geometric object that satisfies the given geometric properties in GeoGebra". *After 6 hours of study, all students had the ability to create three-dimensional objects corresponding to the exercises in the current Geometry textbook 11. Students' product files have been gathered into an ebook posted on the* "Classroom Resources" *of the GeoGebra website. Research shows that students have quick access to this new technology, but it also raises the need to study teaching situations with the integration of this technology in the direction of generating mathematical knowledge.*

Keywords: Augmented Reality; GeoGebra; Spatial Geometry; Teacher Education

1. Introduction

Humans entered the third millennium with brilliant achievements in science and technology. Today, technology has been drastically changing the way people think, work, communicate; and education has also been not outside this influence. Indeed, the subject of education is now a new generation, the "digital generation" - born and mature in a digital age, with characteristics very different from previous generations. Therefore, teachers need more advanced methods to attract attention, evoke motivation and teach more effectively (Erdem, 2017). From the beginning of this century, NCTM (2000) predicted that

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"Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p.24).

In recent decades, educators have sought, tested, and implemented many technologies into the education system. Among the multitude of different technologies applied in education around the world, augmented reality (AR) is one of the newest technologies. Along with the growth of computing power, the delicacy of the screens, input devices and especially the popularity of mobile devices, the effectiveness of applications, AR technology has been spreading in many fields, such as entertainment, industry, medicine, construction, tourism, and military (Azuma, 1997; Hantono et al., 2018). In the education sector, it has been identified as advanced technology, attracting the attention of researchers of education and there are more and more publications of this technology (Adeeb, & Hanna, 2018; Omar et al., 2019; Saltan, & Arslan, 2017).

By establishing a bridge between the virtual elements as the models of mathematics abstract concepts to the real world, AR seems to be in accordance with the trend of Realistic Mathematics Education with the ability to visualize, allowing manipulations on geometric objects. Therefore, it has great potentials in teaching and learning geometry. Also, a key objective of teaching geometry, mentioned in many education systems of different countries, is the capacity of spatial abilities; some studies have shown the usefulness of AR in training, enhancing spatial abilities of learners (Ali et al., 2017; Kaufmann et al., 2005; Kaufmann, & Schmalstieg, 2003; Lin et al., 2015).

As educators all know, teaching with technology has many potentials, but it is also a big challenge. Many studies have raised concerns about teachers' competence and understanding of technology integration in teaching (Dockendorff & Solar, 2018). In this context, this article introduces some initial results of ARUE project, related to the preparation for the integration of AR feature of GeoGebra into teaching spatial geometry to pre-service mathematics teachers at Ho Chi Minh City University of Education.

2. Literature review

2.1. Augmented reality and Education

According to Carmigniani and Furht (2011), AR's development history can be traced back to Morton Heilig's cinematic ideas about engaging viewers in on-screen activities by effectively influencing all senses in the 1950s. Many studies (Azuma et al., 2001; Carmigniani, & Furht, 2011; Hantono et al., 2018) show that Ivan Sutherland was the first to complete an AR function system using an optical see-through head-mounted display in the 1960s. Recognizing the potential of AR, researchers and designers have continually improved AR systems to serve a variety of purposes, and of course, including the educational field.

In research works, the term "Augmented Reality" is defined by researchers in many different ways (Wu et al., 2013). At first, AR was described as a mixture of reality and virtuality based on/accompanying technology with the support of technological devices, such as computers, handheld devices, head-mounted displays, etc. Later, researchers, designers, and educators understood the term in a broader sense. Azuma (1997) and Azuma et al. (2001) established it, in an attempt to avoid referring to a particular technology, as a system with three characteristics: combining real and virtual objects in a real environment, running interactively in real-time, registering real and virtual objects. Klopfer and Squire (2008) defined it as "a situation in which a real-world context is dynamically overlaid with coherent location or context-sensitive virtual information" (p.205). Carmigniani and Furht (2011) considered AR as "a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it" (p.3). Milgram and Kishimo (1994) discussed AR as "a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it" (p.3).

In the last few years, mobile devices, such as tablets and smartphones, have become increasingly popular. To cater to user tastes, manufacturers are constantly cramming in more features and continually improving their performance. They become a suitable platform for building diverse applications and productive deployment of services. Users can now download and install as many applications as they need. By providing a digitally improved and enhanced three-dimensional interpretation of the physical world, manufacturers are increasingly interested in embedding AR technology into small mobile devices in the user's hands; since then, people have referred to the term "Mobile augmented reality". Sánchez-Acevedo et al. (2017) defined it as “the perceived augmented reality via devices that users always carry with them” (p.154). The mobile augmented reality is the technology that this article is interested in.

Table 1 presents a summary of two review studies related to AR integration in the education of Bacca et al. (2014) and Altinpulluk (2019).

Table 1. *A summary of review studies of Bacca et al. (2014) and Altinpulluk (2019)*

	Bacca et al. (2014)	**Altinpulluk (2019)**
Data analysis	32 articles in 6 SSCI and SCI journals from 2003 to 2013	58 articles in 8 SSCI journals from 2006 to 2016
Changes in the number of articles published by year	increase	increase

Research methods used mostly in articles on AR	mixed	mixed quantitative
Data collection method	questionnaire survey interview	questionnaire test
Advantage for AR	learning gains, performance motivation interaction collaboration engagement attitudes	achievement/performance motivation interaction cooperation/collaboration engagement attitude satisfaction retention evaluation usability attention behavior change communication enjoyment skill improving user experience treatment ***perception*** ***visualization***
Limitation for AR	Difficulties maintaining superimposed information Paying too much attention to virtual information The consideration of AR as an intrusive technology	

Overview studies of Bacca et al. (2014) and Altinpulluk (2019) also point to the lack of AR studies in the field of teacher training and mathematics. The mathematics teacher training on AR is the area that ARUE project is interested in, in particular, the project focuses on exploiting the benefits of perception and visualization that AR technology brings.

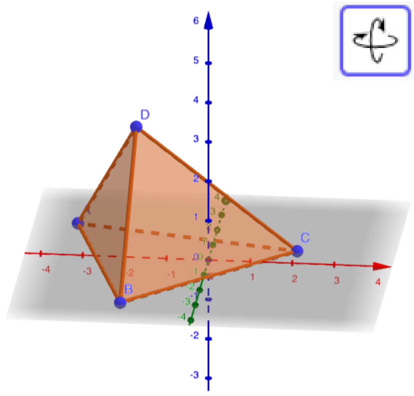
2.2. Augmented reality and GeoGebra

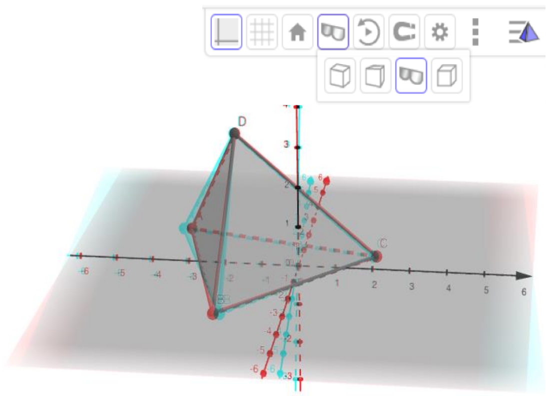
To implement AR technology, besides the hardware devices, the software is required - acting as the soul of this technology. In general, softwares that support math teaching can be divided into two main types: Computer Algebra System (CAS) and Dynamic Geometry

Sofware (DGS). In particular, CAS programs mainly support calculation on symbolic expressions, while CAS programs allow creating, managing and creating geometric figures according to Euclidean principles (Hall, & Chamblee, 2013). Some of the well-known and widely used DGS include Logo, Geometer's Sketchpad, Cabri, GeoGebra.

The ARUE project pays attention to GeoGebra for three reasons. First, it has many powerful features. Indeed, GeoGebra combines both CAS and DGS (Dockendorff, & Solar, 2018; Hall, & Chamblee, 2013) to become a "dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package" (GeoGebra website). It uses dynamically linked multiple representations for mathematical objects though its graphical, algebraic, and spreadsheet view (Hohenwarter, & Lavicza, 2010). GeoGebra allows a productive deployment of learning activities in math education. Second, t is an open-source software freely available for non-commercial users. The financial advantage allows the integration of GeoGebra into the classrooms of developing countries. Thirst, it is geared towards developing a large user community around the world. Indeed, researchers and teachers can easily create and share activities in Classroom Resources.

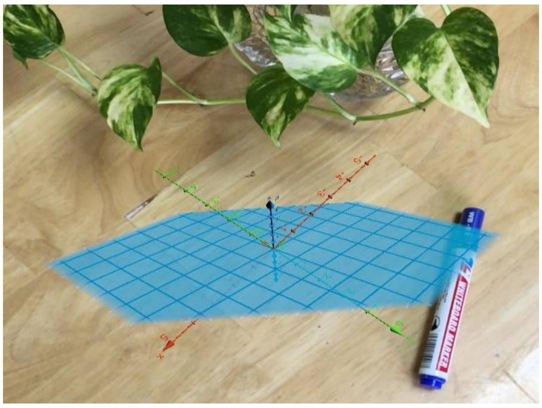
GeoGebra includes now free offline apps for iOS, Android, Windows, Mac, Chromebook and Linux following: Graphing Calculator, Geometry, GeoGebra Classic (5, 6), 3D Calculator, Augmented Reality. To visualize the objects of three-dimensional geometry, GeoGebra offers many solutions. First, after building a tool for drawing two-dimensional objects ("Geometry" views) on Geometry/Geometry Classic, GeoGebra adds a "3D Graphics" view to draw three-dimensional objects (Figure 1a). Users can view this dynamic object from different angles using the "Rotate 3D Graphics View" tool. Next, GeoGebra developed the "Projection for 3D Glasses" mode (from version 5) in addition to other display modes (with different projections) such as "Parallel Projection", "Perspective Projection", "Oblique projection" (Figure 1b). This feature results in anaglyph representations of three-dimensional geometric objects when users use a pair of anaglyph 3D glasses. In September 2017, "Augmented Reality", an application developed on mobile devices, was born with the ability to perform virtual reality graphs of two-variable functions and a limited number of pre-created objects. (Figure 1c). However, this application is not suitable for the representation of spatial geometry objects in teaching. In July 2019, the "3D Calculator" application was developed on mobile devices to represent three-dimensional geometric objects using AR technology (Figure 1d). It is the app used in this study.

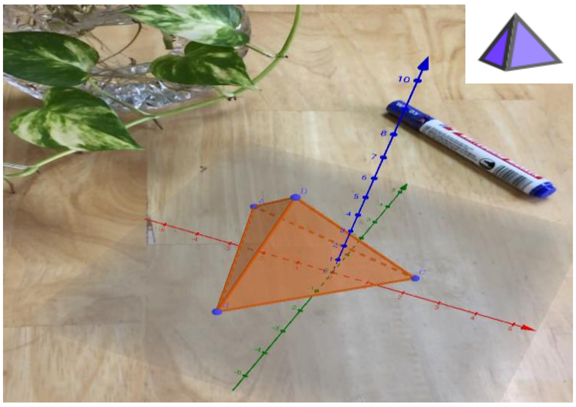




a) Perspective "*3D Graphics*" of GeoGebra Classic 6

b) Mode "*Projection for 3D Glasses*" of GeoGebra Classic 6





c) App "*Augmented Reality*"

d) App "*3D Calculator*"

Figure 1. *Representation of three-dimensional geometric objects on GeoGebra*

3. Context

In Ho Chi Minh City University of Education, the Higher Education program - Bachelor of Teaching Mathematics of Department of Mathematics includes 135 credits of different modules. These modules can be divided into three sections: General, Pure mathematics, Mathematics education.

- General Section: providing general knowledge of philosophy, law, informatics, foreign language, and some specialized pedagogical knowledge such as psychology, education.

- Pure mathematics Section: providing pure mathematics knowledge in four sub-disciplines: Calculus, Algebra, Geometry, Applied Mathematics.

- Mathematics education Section: providing knowledge and practice in teaching mathematics with subjects: Introduction of Didactics of Mathematics, Didactic of Algebra and Calculus, Didactic of Geometry, Testing, and Assessment of mathematics learning results in high school, Application of Information Technology in Teaching Mathematics, Theory of didactical situations, Basis of secondary mathematics education, Mathematics curriculum development in high school, Practical activities in mathematics teaching, Construction and function of knowledge in teaching mathematics.

GeoGebra is taught in the "Application of Information Technology in Teaching Mathematics" module. It is a compulsory module, with two credits. The module provides theories about teaching mathematics in the information technology environment, how to use some teaching softwares and integrate them into the design of teaching situations that students have learned in the module Introduction of Didactics of Mathematics. In particular, the teaching software will be exploited in the following aspects: numerical experiments, geometric experiments, and illustrations. The content of the module is described in Figure 2. In chapter 1, students are familiar with applications that can be used in teaching mathematics. In chapter 2, GeoGebra is introduced as a specialized application for teaching mathematics. In chapter 3, GeoGebra acts as a technological vehicle to develop situations of teaching (illustrating or experimenting) concepts, theorems, and math problems.

Chapter 1. Exploiting information technology applications in teaching mathematics

1.1. Exploiting office software in teaching mathematics

1.2. Exploiting web applications in teaching math

1.3. Exploiting mobile applications in teaching mathematics

Chapter 2. Dynamic mathematics software GeoGebra

2.1. Overview of the software

2.2. Features of the software

2.3. Shared products from the users' community of GeoGebra

Chapter 3. Teaching in the information technology environment

3.1. The concept of "environment" in teaching mathematics

3.2. The transformation of mathematical knowledge in the information technology environment

3.3. Exploiting dynamic mathematics software: illustration and experiment

3.4. Some teaching situations in the information technology environment

Figure 2. *Contents of the module*
"Application of Information Technology in Teaching Mathematics"

4. Method

With the spirit of ensuring that students get the latest updated technology skills when they graduate, GeoGebra's 3D Calculator application, as soon as it appeared in July 2019, had been put into teaching for students in the above module right from the 2019-2020 school year. The deployment process consists of three phases:

Phase 1 (time of teaching item 1.3 of chapter 1)**:** Students were introduced to GeoGebra's 3D Calculator application in the Apple Store or Google Play app store. Students will install the application on a personal smartphone and watch a demonstration on the AR technology of geometric objects available on the Classroom Resources of the GeoGebra website.

Phase 2 (at the time of teaching chapter 2)**:** Students practice on GeoGebra to create spatial geometric objects in chapter 2. This mission is the key for students to own three-dimensional geometric objects on-demand then represent it with AR technology on the 3D Calculator app installed on a personal smartphone.

Phase 3: Each student is required to create three-dimensional objects in an exercise in Geometry 11 textbook. The student's product files will then be aggregated and posted to "Classroom Resources". These files are a (social) contribution of students to the (open) joint database of the GeoGebra users community. Later, when practicing or teaching in the classroom, students themselves can reuse the resources of 3D Augmented Reality that they have constructed.

Below, the article focuses on describing learning tasks (in phase 2) to help 62 third-year students grasp the technical characteristics of the application to create spatial geometric objects in this application. These tasks are conducted in 2 working days (3 hours/session). Students work individually on computers with GeoGebra Classic installed (version 5 or 6). The main type of task that students need to perform is "Create a geometric object that satisfies the given geometric properties in GeoGebra". The geometric properties will be changed through tasks to ensure students mobilize all the features and have the ability to transform the construction requirements to fit the constraints and buttons provided by GeoGebra. After each task, a student presents his solution in front of other students in the class. Next, the whole class discusses the adequacy and reasonableness of the solution. At the same time, in each assignment, students are also encouraged to perform in different ways.

In session 1, students will build two-dimensional objects on the Geometry interface.

Task 2D.1: Creating a square.

Task 2D.2: Creating an isosceles right triangle.

Task 2D.3: Creating an equilateral triangle.

Task 2D.4: Creating a half equilateral triangle.

Task 2D.5: Creating the circumcircle of a given triangle.

Task 2D.6: Creating the incircle of a given triangle.

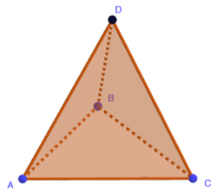
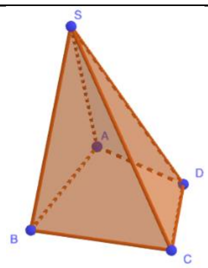
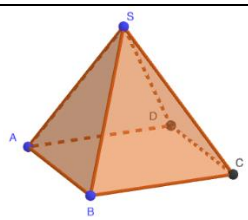
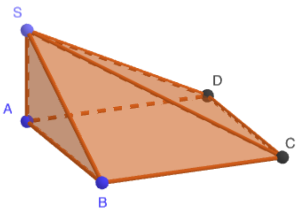
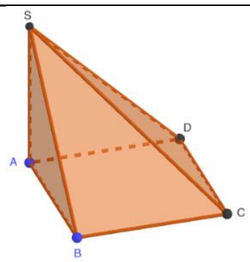
Task 2D.6: Creating the excircles of a given triangle.

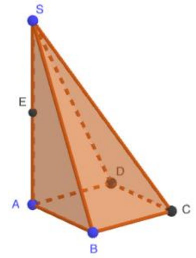
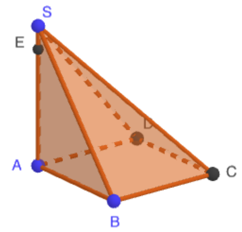
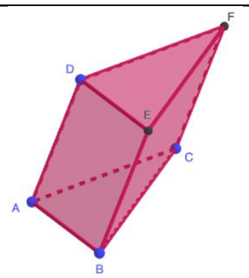
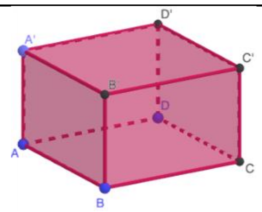
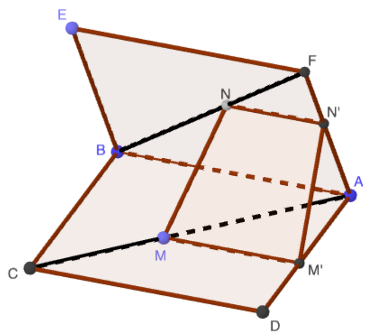
Task 2D.7: Creating the Euler line corresponding to a given triangle.

Task 2D.8: Creating the Euler circle corresponding to a given triangle.

In session 2, after becoming familiar with rendering tools (in two dimensions), students were asked to construct three-dimensional objects on the 3D Graphics interface (Table 1).

Table 1. *Tasks in session 2*

Nhiệm vụ	Đối tượng hình học	Mục đích
Task 3D.1: Creating a tetrahedron.		Creating objects (points) in the third dimension.
Task 3D.2a: Creating a quadrilateral pyramid S.ABCD.		Consolidation
Task 3D.2b: Creating a quadrilateral pyramid S.ABCD, with ABCD as a square.		Incorporating parallel, perpendicular elements (in the plane)
Task 3D.2c: Creating a quadrilateral pyramid S.ABCD, with ABCD as a square, SA is perpendicular to the plane (ABCD).		Incorporating perpendicular elements in space (perpendicular line to the plane)
Task 3D.2d: Creating a quadrilateral pyramid S.ABCD, with ABCD as a square, SA is perpendicular to the plane (ABCD), SA=AB.		Incorporating dimension measurement in space (via sphere)

<table>
<tr><td>Task 3D.2e: Creating a quadrilateral pyramid S.ABCD, with ABCD as a square, SA is perpendicular to the plane (ABCD), SA=2AB.</td><td></td><td rowspan="2">Controlling measurement elements (through transformations in space)</td></tr>
<tr><td>Task 3D.2f: Creating a quadrilateral pyramid S.ABCD, with ABCD as a square, SA is perpendicular to the plane (ABCD), SA=1,2.AB.</td><td></td></tr>
<tr><td>Task 3D.3: Creating a triangular prism</td><td></td><td rowspan="2">Consolidation</td></tr>
<tr><td>Task 3D.4: Creating a rectangular prism</td><td></td></tr>
<tr><td>Task 3D.5: Creating the geometric object in exercise 3 on page 50 (textbook Geometry 11): “Two squares ABCD and ABEF share the same side AB and lie in two different planes. On the diagonal lines AC and BF, we take the points M, N so that AM=BN. The plane (P) contains MN and is parallel to AB and cuts AD and AF at M’ and N’ respectively.”</td><td></td><td>Advancing and familiarizing with creating geometric objects in textbook exercises.</td></tr>
</table>

5. Results

In phase 1, students could install apps on individual smartphones at home or via 4G in the classroom. The AR technology of the app made students very excited.

In phase 2, all students complete (on their own or in exchange with classmates) the tasks set out by exploiting the tools provided by GeoGebra. Among the recommended tasks, the task 3D.5 caused the most difficulties for students. First, students could not create the square ABEF that is not in the same plane as that of the square ABCD created by students using the "Regular Polygone" tool button. This difficulty arose from the difference between the perpendicular elements in the plane (students could quickly solve it in 2D.1) and perpendicular elements in space. Second, students could not create a point N on BF so that BN = AM (the point M already existed). The second difficulty arose from the fact that students had not yet recognized the "Sphere" tool as a means to create measurement elements (e.g., equality of length).

In phase 3, all students created geometric objects in their assigned assignments (textbooks). Student production files have been gathered into an ebook of drawings of all spatial geometry exercises in the current textbook (Figure 3) on the "Classroom Resources" of the website https://www.geogebra.org/materials.

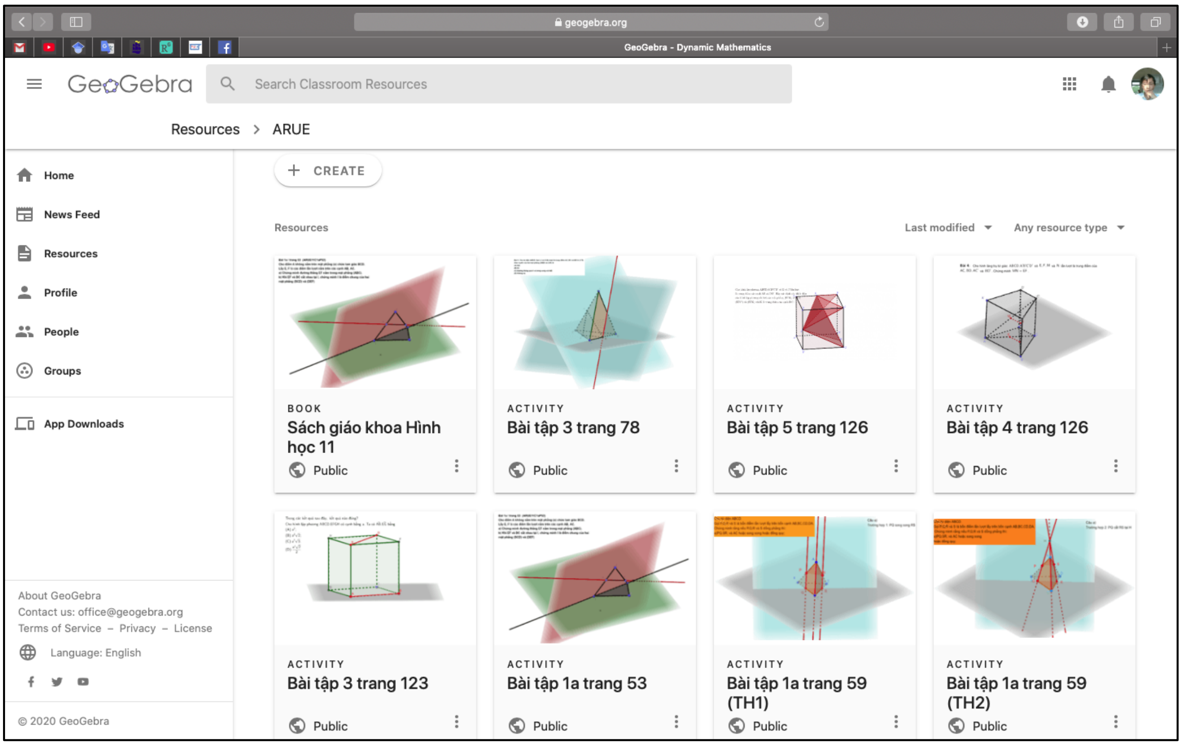


Figure 3. *Screen capture of Classroom Resources interface with some 3D drawings that students contributed*

6. Discussion

Witnessing the growing spread of AR technology in different fields and life, educators are increasingly interested in the application and exploitation of this technology in their fields. In the last 20 years, many works have shown the benefits of this technology in education. In particular, in mathematical education, it allows enhancing perception and visualization. This study refers to training teachers in accessing this technology through GeoGebra's newly introduced application: "3D Calculator". The research results show that mathematics pre-service teacher of the Ho Chi Minh City University of Education can quickly acquire this technology with a system of tasks designed and calibrated based on the task type "Create a geometric object that satisfies the given geometric properties in GeoGebra".

In a broader sense, this research only meets the requirements to equip pre-service teachers with technical features of the application. The more important question is how this technology should be used in mathematics teaching activities. It should not stop at illustration, perspective representation, for example, but should advance to a higher level: giving birth to a mathematics knowledge. To be able to meet this complex requirement, pre-service teachers need to be introduced to and work on teaching situations where AR technology is associated with teaching requirements, especially in the Mathematics program of the new general education program (2018), and cognitive characteristics of mathematical knowledge. Specifically, the question mathematics educators might be interested in is: “How can the blend between reality and virtualization of AR technology be harnessed in teaching spatial geometry in high school, which is seen as a mathematical model of the physical space we live in?” Such research is an important future direction for developing and seeking additional benefits of AR technology in mathematics education.

❖ ***Conflict of Interest:*** *Author have no conflict of interest to declare.*

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ĐÀO TẠO SINH VIÊN SƯ PHẠM TOÁN SỬ DỤNG CÔNG NGHỆ THỰC TẠI ẢO TĂNG CƯỜNG: TRƯỜNG HỢP ỨNG DỤNG "3D CALCULATOR"

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TÓM TẮT

Trong mười năm qua, cùng với sự phổ biến của các thiết bị di động, công nghệ thực tại ảo tăng cường đang ngày càng được ứng dụng rộng rãi trong nhiều lĩnh vực. Đặc biệt, nhiều nghiên cứu đã chỉ ra những ích lợi của nó đối với giáo dục. Trong bối cảnh đó, bài viết khắc hoạ việc cập nhật công nghệ mới này trong đào tạo sinh viên sư phạm Toán tại Trường Đại học Sư phạm Thành phố Hồ Chí Minh. Cụ thể, 62 sinh viên năm 3 đã được đào tạo sử dụng ứng dụng "3D Calculator" *(chỉ mới được công bố vào tháng 7/2019) thông qua việc thực hiện các nhiệm vụ kiểu* "Tạo một đối tượng hình học thoả mãn các tính chất hình học cho trước trong GeoGebra". *Sau 6 giờ học, tất cả sinh viên đều có khả năng tạo ra các đối tượng ba chiều ứng với các bài tập trong sách giáo khoa Hình học 11 hiện hành. Các file sản phẩm của sinh viên đã được tập hợp thành ebook đăng trên* "Classroom Resources" *của trang web GeoGebra. Nghiên cứu cho thấy khả năng tiếp cận nhanh chóng của sinh viên đối với công nghệ mới này, nhưng đồng thời cũng đặt ra vấn đề cần nghiên cứu những tình huống dạy học với sự tích hợp của công nghệ này theo hướng khai sinh tri thức toán.*

Từ khóa: thực tại ảo tăng cường; GeoGebra; Hình học không gian; đào tạo giáo viên