Augmented reality: a new teaching/ learning method in military higher education in Europe. Overview of implementation of digitalization in defence higher education project

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Abstract: *Even if the military higher education system has a special regime and can be associated with a vocational education, it adapts to the surrounding reality. It must ensure the security necessary for the civilian environment and face challenges in everyday life. This paper presents the intro-duction of augmented reality (AR) in military higher through a project entitled Implementation of Digitalization in Defence Higher Education. The project was proposed and developed through a partnership comprising four institutional teams of teachers and students. Their goal was to identify themes from the study programs that could be aligned with the project's objectives and contribute to the modernization of educational resources and teaching materials. Educational resources were developed for 12 topics from the study program, including augmented reality applications for 4 of these topics. Particularly noteworthy are the opinions of students and teachers regarding the use of AR in the educational process. The paper highlights changes in the perception of using augmented reality in the educational process by students and teachers within the military system. Training military students to interact effectively with military technical systems requires continual updates to training methods and active participation from both teachers and students in enhancing practical applications for technical and non-technical disciplines. Introducing augmented reality into the military educational process as an innovative teaching method posed significant challenges, particularly in terms of using the software needed to create AR applications. The partners involved in the project development considered the introduction of augmented reality in the educational military process as an innovative teaching method and hope to continue developing AR applications for as many topics as possible.*

Keywords: augmented reality, adaptive and intelligent educational systems, digitalization, learning environments, military system.

1. Introduction

The premises and objectives for the digitalization process and the introduction of Augmented Reality in educational process are presented hereinafter.

The digitalization of educational resources and the development of augmented reality (AR) applications were carried out under the aegis of the

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Implementation of Digitalization in Defence Higher Education (DDHE) project. The project took place over two years and was completed in March 2023. The project partners were the Vasil Levski National Military University (NMU), Hellenic Air Force Academy (HAFA), War Studies University (WSU) and Henri Coanda Air Force Academy (AFAHC). The DDHE project was submitted during the pandemic, as a result of unfavourable conditions for face-to-face education, especially one dedicated to technical disciplines that require many practical applications. The project tried to answer the following questions.

The first question was whether military higher education was fully prepared to switch to the online system.

The second question is: Are teachers open to finding and developing new teaching methods, especially for practical applications that connect theory with the real world?

The third question is: What is the level of knowledge of teachers and students in the fields of digitalization and augmented reality? In fact, project development answers the question: can the project manager form a team that successfully completes a project that aims to answer the first three questions?

Moreover, the project team had to take into consideration that the lectures needed didactic materials to support theoretical information. Examples include theories of electricity, propagation of electromagnetic waves or measures and countermeasures of electronic warfare. In the context of military higher education that is carried out within the project's partner military universities, but also within other military and civilian universities, technical subjects can be found in study programs for specializations such as Electronic Warfare and Cybersecurity and more. Antennas and electromagnetic waves propagation, Measurements in telecommunications, and Airspace surveillance are disciplines with accentuated applicative characteristics that could not be fully adapted to the pandemic period.

The first survey was administered to the students of the four partner universities to determine the needs and the stage from which the project started. To the question: "What do you think about the need to develop learning resources for the online teach-ing/learning system (in the context of the pandemic)?" The percentages of answers, in the different categories, were as follows: 64% of respondents for laboratories and ap-plications (equipment, access) and 58.9% of respondents for interactive teaching methods.

As a result, the first objective of the project was to convert of theoretical infor-mation into a digital format that is accessible to online/distance learning. If this proved to be a not difficult process, the same cannot be said about the second objective proposed by the university teams: the introduction of AR applications.

The study conducted by institutional teams on the existence of augmented reality (AR) applications dedicated to technical military higher education resulted in the following (Military VR, url):

1. Most of the companies producing software (Champney, 2015; Amaguaña et.al, 2018):

1.1. have developed applications for:

- tactical training on the battlefield,
- applications for flight simulators.

1.2. have developed almost no applications dedicated to the theory and operation of technical devices and systems that would help understand the physical phenomena that could form the skills that a future officer should possess.

Other observations resulting from the study carried out by the institutional teams:

2. Companies producing software have AR technology and applications dedicated to real battlefield situations before dedicated applications for training future specialists in various specialized branches (from engineers to combatants) (Augmented Reality (AR) in Defence; Augmented Reality and Virtual Reality; Is the Augmented Reality; Army goes deep into VR/AR).

The project teams, initially made up of professors belonging to the four mentioned universities, analyzed the existence in the libraries of the four partner universities of some sections that would contain educational resources in digital format for the subjects in the study programs and the possibility of conducting classes dedicated to the prac-tical applications of technical disciplines at a high-quality level under the conditions of an online educational system.

3. The financial shortages in some universities accentuate the gap between the applications developed by software companies and their introduction into the educational process.

4. Educational institutions and teachers have attempted to develop dedicated AR applications in both military and civil systems (Kesima 2012; Cai 2014; Elmqaddem 2019; Mao, Sun & Chen, 2017; Wang et al, 2020).

As a result of these observations, the stages in which the DDHE project had to proceed, were established.

A second survey was conducted to determine the degree of preparation of the four military universities involved in the project for the development and use of AR systems.

We observed (see Figure 1) that 76% (sum of the first 3 columns in figure 1.a.) of the students did not know or did not know much about AR, almost 65% wanted to learn about AR (sum of the last 2 columns in figure 1.b.) and 58% (sum of the last 2 columns in figure 1.c.) totally agreed to get involved in the development of AR applications.

The analysis of these answers was not encouraging, about 10 percent were lost in the number of students who wanted to know more about AR and almost 20

percent of those who wanted to get involved in the development of AR applications. This means that only 58% wanted to find out and do something in the AR field. The percentages generated questions about the process of updating the didactic act considering that AR technology has been included in the daily activity of the military for several years, it is true that only in a few cases, especially in tactical applications on the battlefield, some military systems (such as heads-up-display), in night vision systems that allow soldiers to operate effectively in low or nighttime conditions (Champney, 2015).

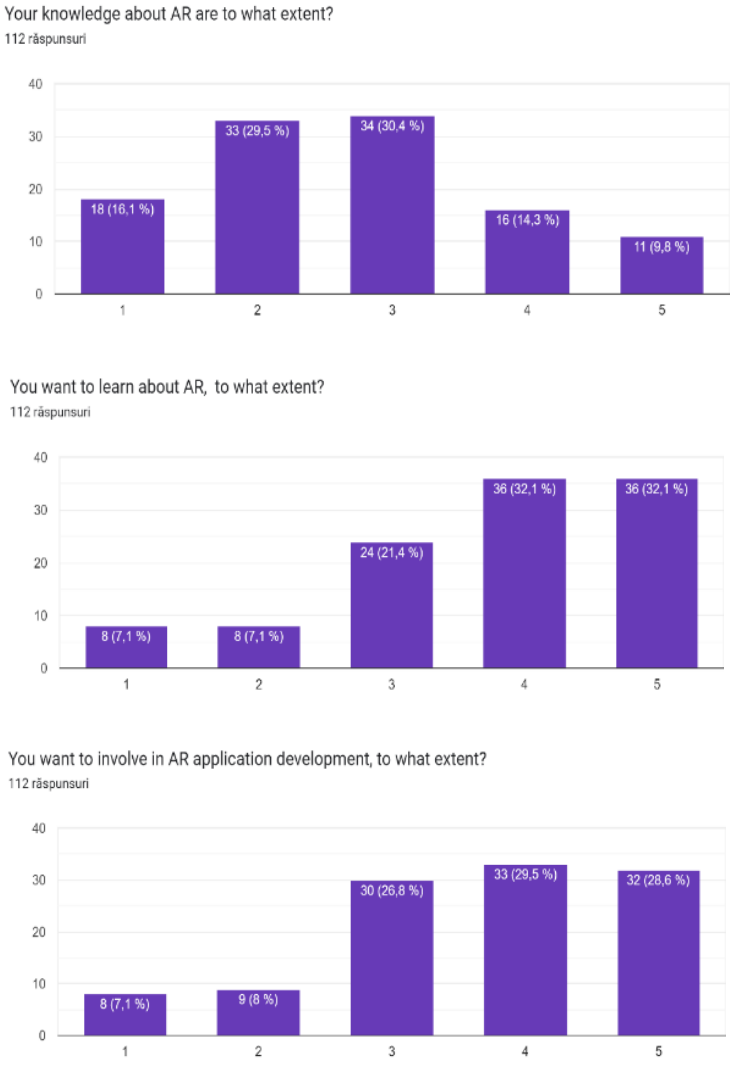


Figure 1. Student Responses to the "Your knowledge about AR are to what extent?" and "You want to learn about AR, to what extent"

2. Materials and methods

In the context of an accelerated digitalization process, we observed that the answers obtained from the applied survey were contradictory to some extent. To solve the problems identified by the questions applied to the students, along with the two pre-viously stated objectives, a third objective was imposed: the organization of an online library that would contain the results of the first two objectives.

The institutional teams formed at the beginning of the project, from a number of 19 professors belonging to the partner universities in the project, quickly solved the first objective by developing the educational resources in digital format that contain lectures, exercises, applications and quizzes. These resources have been created for 14 disciplines whose subject matter covers very different fields, from electronics to defence tactics or even diplomacy. All educational resources created in digital format are freely available on the website of the AFAHC library and the DDHE project.

Augmented reality applications, which constituted the second objective, and are the main subjects of the present work, were a real challenge. From the 14 disciplines, six were chosen for which the respective applications were developed. These disciplines were: Measurement in telecommunication, Electronic warfare, War games, Diplomatic protocol, Radar, and Air surveillance.

Disciplines were chosen belonging to:

- the technical field/ of electricity applied in the field of defence and security;
- the field of diplomacy;
- the field of combat tactics.

Before realizing the second objective of the project, a questionnaire was administered to teachers of the institutional teams. They answered questions such as: “Knowledge and information about the AR applications (2nd objective named, for the project, 2nd intellectual output) at the beginning of C2” and “Hope of gaining infor-mation about your own tasks regarding AR applications”. C2 was a short-term training dedicated to teachers from the project. The answers to the questionnaire were on a scale from 1 to 5, where 1 represented very unsatisfied, and 5 represented very satisfied (see Figure 2).

A survey was administered to professors from the partner institutions in the pro-ject to provide an overview of the knowledge regarding AR technology at the level of the entire academic staff of the four universities.

The answers reinforced observations regarding the introduction and development of AR applications in military universities (see Figure 3). The three questions regarding AR applications were: “Knowledge and information about the AR applications at the beginning of 2021 academic year”, “Hope of gaining

information about AR applications developed by your institution" and "Would you like to use AR in the teaching process".

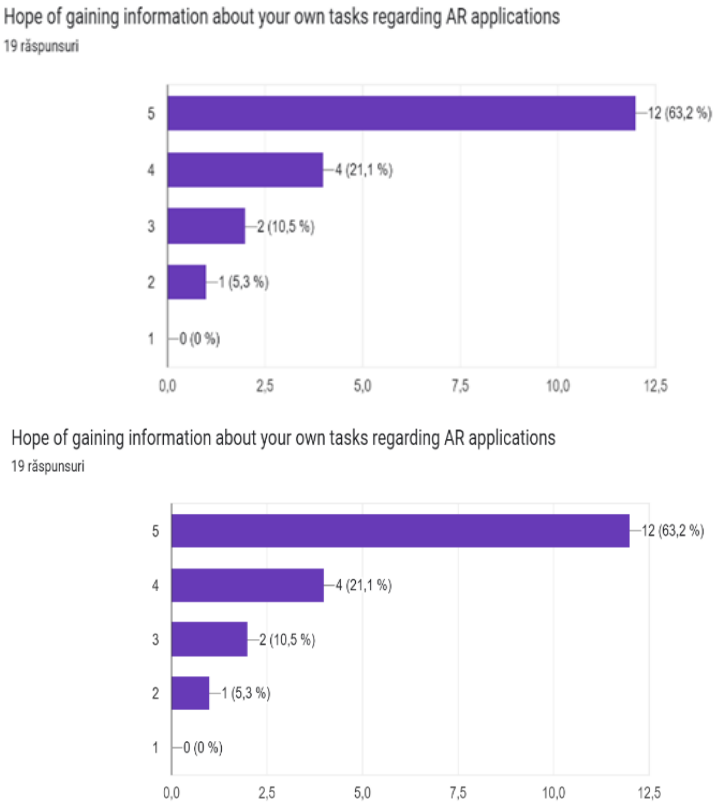


Figure 2. Teachers' answers to the set of questions regarding the objective of AR applications

The survey was administered to 97 people, not very many but not few, considering the relatively small number of academic staff involved in the teaching process in military universities. We observed:

- the lack of information on AR - almost 80% of the teachers declared that they had almost no information on AR and no professor declared that they had enough in-formation;
- the percentage is high regarding teachers' desire to learn information about AR technology (85% of the respondents – last column on figure 3.b) but also a certain reticence regarding the use of AR applications in the teaching process. Approximately 30% (last column on figure 3.c) were not completely convinced that they would use AR in process teaching. On the other hand, none of the participants categorically refused to use AR.

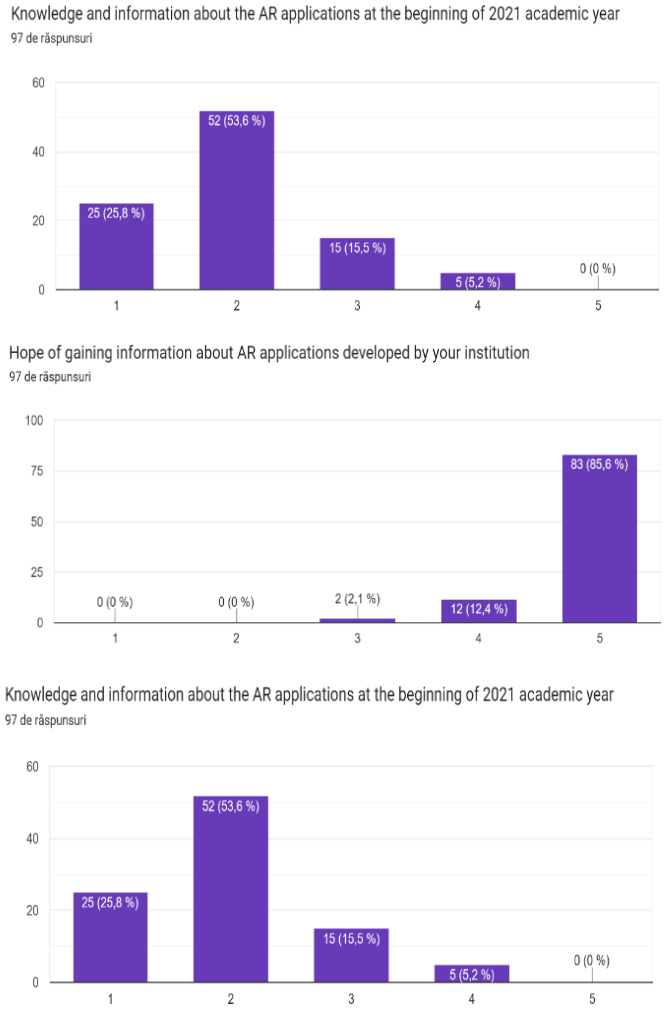


Figure 3. The responses of the academic staff regarding the knowledge of AR technologies

Thus, the development of AR applications has become a priority for this project. Students were coopted into institutional teams, with five students for each partner university in the project. The number of students involved was not large because of limited number of project members accepted through approval. Stages where students were involved: AR application development, AR application testing and evaluation.

To obtain AR applications, the following steps were taken:

1. Existence of images, from several angles, of the object under study. The images were correlated with the information provided by the educational resources within the first objective.

2. Creating objects in 2D or 3D formats, respectively, creating animations using Blender/Unity software. Among the software12 dedicated to creating animations, Unity software was preferred. Reason: This software is among the most widely used video game animations. This versatile and powerful application has been used in various fields, including virtual, augmented, and mixed reality. The platform provides users with a wide range of tools and options to ease the application development process. Unity is an application that unifies multiple possibilities and provides programmers with the opportunity to develop applications for the main smart devices used by users, such as computers, smartphones, VR glasses, and AR. One of the advantages of Unity is its compatibility with smart devices such as HoloLens 2 glasses.

3. Results

3.1 Objectives and achievements of the project

The most important results of the project refer to obtaining and using augmented reality applications and can be presented under quantitative and qualitative aspects.

The evaluation and testing of the results obtained for the second objective was carried out with the help of HoloLens glasses. In the following, the reasons and method of their use are presented.

The HoloLens 2 glasses can be used in various applications.

Some of the objects in 3D format made by the students which can be shown with the help of HoloLens glasses are presented in Figure 4.

It may not seem very important that images of devices dedicated to electrical measurements can be found in various catalogs and books, but 3D objects made of HoloLens glasses have the advantage of direct interaction. In Figure 4. a spectrum analyzer was presented, and a laboratory lesson played using HoloLens glasses was presented.

Figure 4. Exemplifying AR applications made for the topic Measurement in Telecommunication (DDHE 2023)

Note: What appears to be a simple image is a 3D object that can be viewed from multiple angles, as shown in Figure 5.a and 5.b.

a.

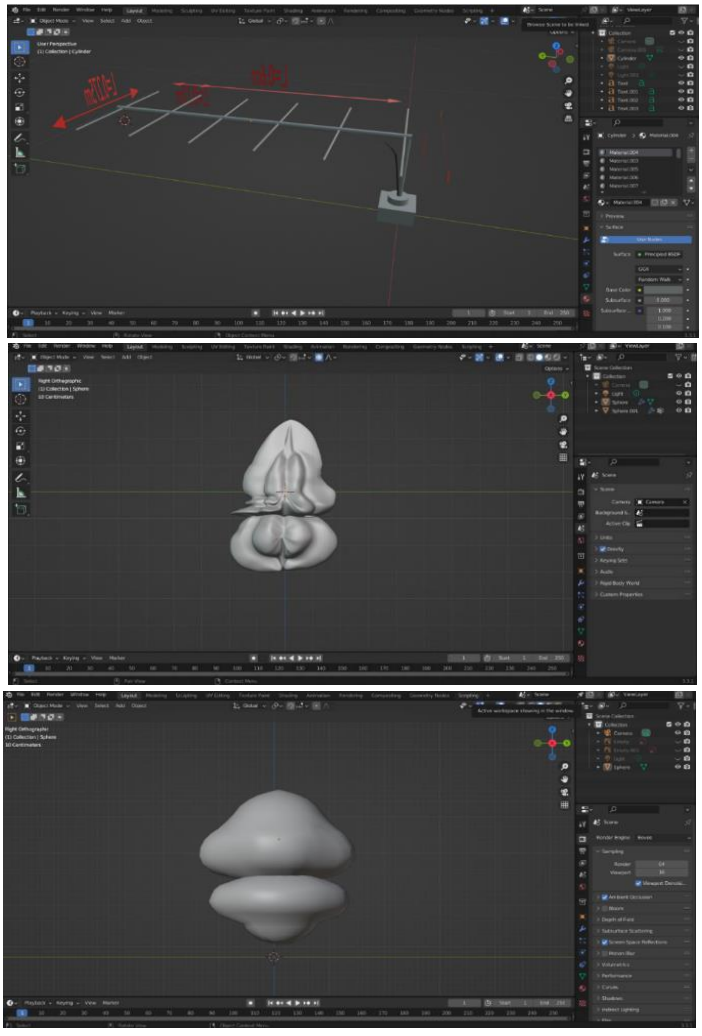
b.

Figure 5. a. 3D images viewed with HoloLens 2 made for the topics Radar, Air Defence, and Air Surveillance; b. Interaction with object designed for Air Surveillance (DDHE 2023)

The objectives of the project presented in this paper were to cover a wide range of fields, from electronics and electronic warfare to diplomatic relations. As multidisci-plinary approach, AR applications have been developed in all these fields. A real chal-lenge was the realization of AR applications for the Diplomatic Protocol discipline. Thus, 3D objects were developed for creating "mise-en-place," the art of organizing an official dinner: from the arrangement and identification of the guests to the way of arranging the cutlery. 3D objects made for this purpose and used on HoloLens glasses are exemplified in Figure 6 (Vakaliuk, 2021).

Figure 6. 3D objects made for Diplomatic Protocol from different angles of view (DDHE 2023)

Figure 7 presents how are created AR applications for the fields of antennas and wave propagation (Blender design for: a. Yagi-Uda: antenna system, b. real characteristics c. simulated characteristics).



a. b. c.

Figure 7. AR applications for the fields of Antennas and wave propagation (Ciuca, 2023)

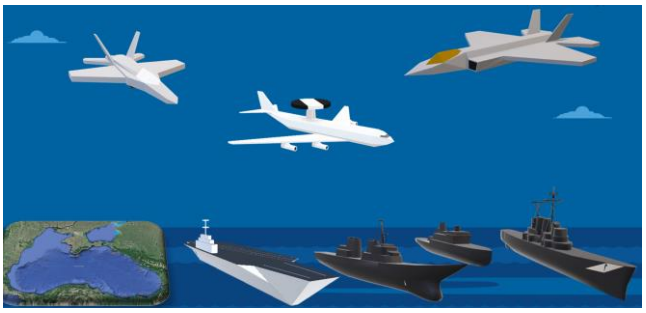
3.2 Involvement of the students

Previously, the percentage of 58% of the surveyed students who wanted to become involved in the development of AR applications were highlighted. Next, AR applications developed and implemented by students in the educational process are presented. Applications corresponding to Antennas and Wave Propagation were the subject of the study of the Yagi-Uda antenna.

This topic was chosen because this type of antenna is found in basic systems that a student uses in Air Surveillance or Electronic Warfare training. The following steps are necessary to obtain the applications:

- obtaining in the laboratory and through MATLAB simulation the images subject to implementation;
- realization of 3D objects to be loaded on the HoloLens glasses;
- realization of animations for created objects.

Figure 8 presents AR applications for the fields of Air Surveillance/Electronic Warfare (a. designing 3D objects using Unity and Visual Studio, b. making and entering buttons in the "Game" mode of the Unity program for electronic surveillance of space).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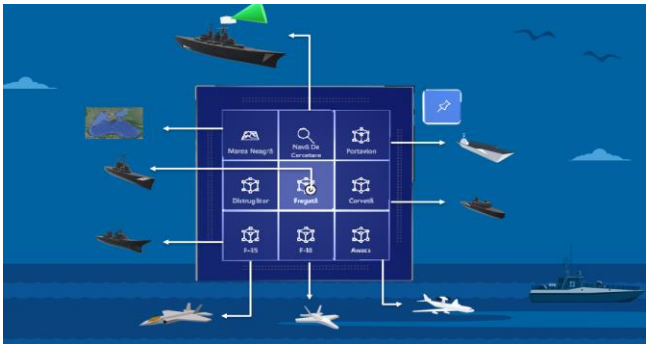
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Figure 8. AR applications for the fields of Air Surveillance / Electronic Warfare (Dascalu, 2023)

4. Discussions

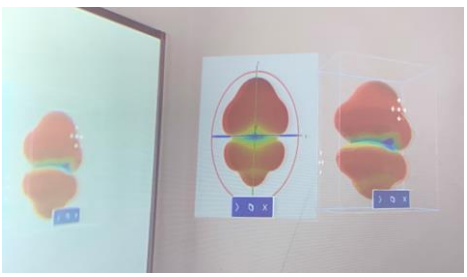
If the question is why animations with 3D objects designed for AR persist, we can state some advantages that are highlighted by the possibility of using them and the HoloLens glasses in synchronous or asynchronous learning processes (Sobon, 2022), in face-to-face systems or online through the connection HoloLens-laptop video projector.

To evaluate the results of the project, both quantitative indicators (visible through the number of educational resources in digital format) and result indicators, respectively qualitative indicators, were used. Through them, the effects and changes expected in the short and medium term following the achievement of the project objectives were evaluated. It was necessary to answer the following questions:

1. By introducing AR applications, has students' understanding and analysis of the taught material increased? The answer is given by two advantages:

- increased immersion: 3D objects designed in real space but viewed in the virtual environment offer a more immersive experience compared to 2D elements or tra-ditional interfaces. Students can see and explore the three-dimensional details of objects, which allows them to form a more accurate and realistic perspective;
- contextual Viewing: 3D objects can be integrated into a student's real environment, providing a contextual view. This means that virtual information can be displayed in specific places, such as instruction labels on equipment, maps projected on walls or 3D diagrams in a room (see Figure 9).

2. Did the number of students involved in the development of AR applications increase at the end of the project compared with when it was completed? This affirmative answer is supported by the increasing number of students whose graduate projects / bachelor's thesis has developed AR applications in various fields of study. For example, at the beginning of the project, no student at Henri Coanda Air Force Academy used AR to complete their graduation thesis. At the end of the project, with a number of 150 graduates, 15 of them used AR to create and present their graduation project.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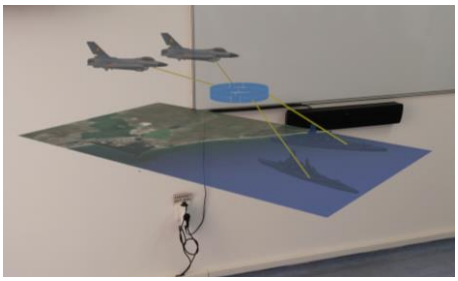
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Figure 9. 3D diagrams or maps projected on the walls of a room in the Antenna and wave propagation and Air Surveillance/Electronic Warfare topics (Dascalu, 2023; Duinea,2023)

The questionnaire administered at the end of the project proved the insights gained by the students, for example, about the effects of AR on the education process (Figure 10).

Figure 10 presents the answers to the question Which of the following statements represents, in your opinion, the biggest gain by using AR applications in the educational process?

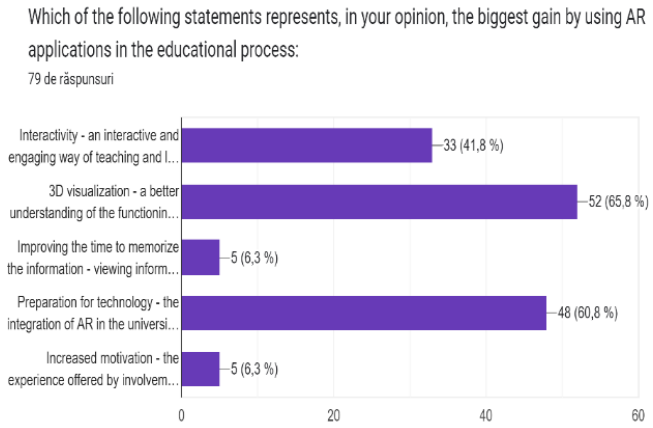

Figure 10. Students' opinion about the gained insights, the effects of the AR application

Three benefits from application we can highlighted:

1) Interactivity - 41% of respondents considered an interactive and engaging way of teaching and learning, (top row).

2) 3D visualization - 67% considered this a method for a better understanding of the functioning of technical systems by visualizing objects and concepts in a three-dimensional space (second row from the top).

3) Preparation for technology - 60% consider that the integration of AR in the university educational process helps familiarize themselves with emerging technolo-gies and tactical actions on battlefields (second row from the bottom).

This means that most students thought of a better way of learning, but also that they accepted AR as part of their future and everyday life.

5. Technological and financial challenges

The entire project was carried out under the pressure of several challenges that imposed limitations on its deliverables. Among these, the following can be mentioned:

- financial, due to the relatively high cost of the HoloLens at the time of its purchase and project development;
- the low degree of knowledge of the programming technique and the AR technology of both the teachers and the students;
- the relatively small number of those involved in this study/project, a number imposed by the reduced funds but also by the number of existing personnel in the four partner universities.

What does continuing the study mean? The development of some AR applications that allow the individual study of technical and practical works and applications dedicated to the existing technical disciplines in the educational programs of the defence system.

This means the realization in augmented reality of some technical guidelines that present the following for each technical application:

- theoretical notions related to the respective technical application;
- the way of working with the technical equipment necessary for the respective application;
- the 3D objects dedicated to the technical application with which each user can interact.

The start of such guidance has already been given. Figure 4 represents an interaction model related in AR with technical systems in specialized laboratories.

The evolution of AR systems and applications and, the transition to the use of mixed reality applications in the educational process of military higher education in the next period will confirm the long-term benefits of this project.

6. Conclusions

The paper is a summary of the Implementation of Digitalization in Defence Higher Education project with its main objectives, the realization of digital educational re-sources and the development of AR applications for different fields of study, whether technical or not.

Why was it considered necessary to create AR applications? The answer to this question can be seen from two points of view. The first refers to the curriculum of topics studied in military universities which includes lectures and practical applica-tions/laboratories in equal percentages. The second is closely related to the satisfaction questionnaire applied to students where 64% considered it necessary for the pandemic period, or for the online educational process, to find a way to adapt the educational process carried out in the laboratories and practical applications.

The same need was noticed by professors who, unfortunately, did not manage to find a method to present the equipment online, the way to work with it and the inter-pretation of the results of practical applications.

The deficiencies discovered during the Covid period raised questions about the modernization of the educational system along its entire course, in different development scenarios (Sobon, 2022).

As a result, the project team concluded that updating the teaching methods and upgrading the equipment and techniques used must be an important concern in the context of the accelerated digitalization of daily activities.

The surveys that were applied allowed the comparison of the level of understanding and satisfaction of the actors involved in the development of the objectives at the beginning and end of the project.

The results of the three survey questions at the end of the project are presented in Figure 11. Questions as" Do you consider that in critical situations, such as Covid/ pandemic, face-to-face or online education process are welcome the AR applications? (first picture of Figure 11), Do you consider that the outcomes of this project, such as AR applications, could provide models to help you in your future work? (second picture of Figure 11), Would you agree to get involved, as students, in the development of AR applications for as many technical subjects of the study plan as possible? (third picture of Figure 11)" highlighted the desire to develop digital skills and to be involved in the development of AR applications.

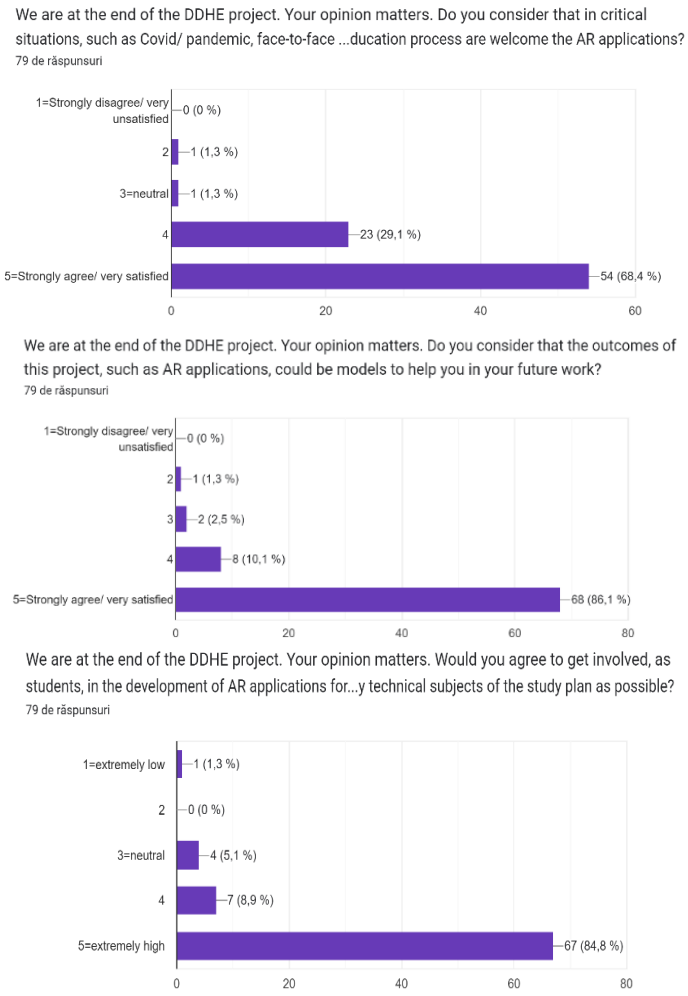

Figure 11. The degree of satisfaction among the members of partner universities in the project at its end

As can be seen at the end of the project the percentage of students who would be actively involved in the development of AR applications reached approximately 85% compared with only 58% at the beginning of the project.

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