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# An Approach to Mobile Augmented Reality in Microcontroller Learning

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**Abstract**: Augmented Reality is a virtual display of information created using a computer on a real environment. Arduino is an open source microcontroller platform. It was aimed to increase the education and learning quality of the students by integrating mobile augmented reality technology into the materials of the microcontroller course. In this study, a mobile augmented reality application was developed in order to see the output of an electronic circuit created using Arduino in the microcontroller course and to get information about the circuit elements. Experimental studies were carried out with a group of 30 students to determine the productivity and quality of this study and a questionnaire about the study was applied to the students after the experiment. It was observed that the experimental applications in which the augmented reality technology was used were performed more efficiently than the experimental applications in the classical methods. In addition, augmented reality technology has introduced an independent learning strategy from the teacher. According to the results of the survey, the mobile augmented reality application was showed to have contributed significantly to the learning process without the need of any expert. In addition, the social presence and motivation of the students were examined with a number of tests and positive results were obtained.

**Keywords:** Augmented reality, Virtual reality, Microcontroller

## Introduction

Augmented Reality (AR) is a display technology developed by adding virtually produced information on the real world environment in real time (Wikipedia, 2018). AR technology is different from Virtual Reality (VR). VR is expeted to live in the world that is prepared virtually in a computer environment. AR is a technology created by placing graphical objects, videos and texts designed on the real world. In other words, AR technology is a technology that constantly connects real and virtual life (Chang et al, 2010). Mobile Augmented Reality is an AR technology that we can carry with us everywhere. Mobile learning facilitates the social learning model with the transformation possibilities provided by digital devices (Cook et al, 2016). The history of AR technology goes back to the 1960s and the first developed system infrastructure was used for both AR and VR. The idea of how two-dimensional objects can be represented in three dimensions has been tested using computers that can perform a limited number of operations (Sutherland, 1968). Emerging technologies such as Mobile AR and VR will gain new knowledge through learning theories based on pedagogical strategies (Aguayo et al, 2017).

The role of mobile technology in education is to actively facilitate the learning process of learners in a number of culturally sensitive and meaningful ways. This process can be designed not only by learning with new learning technologies such as mobile augmented reality, but also by developing socially relevant learning modes

(Aguayo et al, 2017). AR has become an important area of study for mobile learners, with the widespread use of mobile AR browsers allowing 1 users to create and share content (Cochrane et al, 2016), AR technology is widely used in many fields such as medicine, industry, automotive, education, manufacturing and its importance is increasing day by day. According to the New Media Consortium reports, AR is one of the most up-to-date technologies in the education and training process (NMC, 2012). The traditional method of education involves the execution of the information and learning process by a teacher (De Freitas et al, 2009). Learning methods depend on classical paper-based methods and materials (Huang et al, 2012). In addition to current learning methods, more and more useful methods are being explored to improve education and training. Technology evolves began to acquire more space in our lives. As a result, it has begun to be considered that we need to make some changes in our education and teaching methods (Nincarean et al, 2011).

Many factors to improve quality and diversity in the education and training process should be addressed in this process. Taking into consideration the preparation of curriculum contents, teaching strategies, laboratory, libraries, evaluation process and feedback from students, raising qualifications in the education and training process should be considered as the main objective. Therefore, all current and technological applications should be used. Learning can be examined under two conditions: location and time. Depending on these conditions, a number of problems have been raised. Some problems arise such as the inadequacy of physical materials, limited working hours, inability to get help from specialists and difficulty in reaching the laboratory environment. Such difficulties encountered constitute an obstacle in the education and training process. These problems can be solved by providing alternative teaching resources that are used by mobile learning tools (Holzinger et al,2005).

Mobile learning is a big part of our lives. Achieving information quickly and easily increases the importance of mobile applications day by day. When we look at classical learning methods, for example, in textbooks, there are many deficiencies in visual terms. Particularly in micro-controller course textbooks it is seen that there are visual deficiencies in the stages of recognition of circuit and electronic circuit elements. Therefore, learning with mobile application increases the mobility of learners in the learning process and provides a exible working environment (Norman et al, 2011) When mobile learning is viewed as a term, it is the use of portable devices such as mobile phones and tablets as learning tools (Jamali et al,2015). The development of technology provides a great opportunity to capture the change in education and learning process and to provide an engaging environment (Kirkley et al., 2002). According to research, many factors inuence the quality of learning. Among these factors, we can say that the student should develop motivation and learning skills for self-learning (Markwell, 2016). The possibilities provided by AR in teaching and learning have been accepted by educational researchers (Wu et al, 2013). Depending on technological developments, smart devices such as smartphones and tablets have begun to be used intensively in the field of education. Devices such as tablets, smartphones and computers are needed to be able to use the AR applications. With the increase in AR applications, the number of applications developed for mobile devices has increased day by day.

Microprocessor and microcontroller concepts are often confused. The microprocessor consists only of processing and memory units. The microcontroller consists of peripherals such as memory, analogue digital converter and timer. Today, microprocessors are generally used in personal computers. Microcontrollers can often be described as specialized microprocessors designed to perform industrial control and automation tasks. Microcontrollers can often be described as specialized microprocessors designed to perform industrial control and automation tasks. It is difficult to understand the lessons that circuit elements such as microcontrollers are complex. In this study, experimental study, circuit elements, object and purpose of the circuit will attempt to improve the learning ability of students presenting with mobile augmented reality. The Arduino Microcontroller card is used in the electronic experimental applications. The Arduino card only controls and responds to electrical communication. This card interacts with a number of custom components in the real environment. In the questionnaire survey, students will be asked and answered a series of questions such as knowledge acquisition,43 effective learning skills and competence to use AR technology in microcontroller course.

## Method

Experimental materials of microcontroller course are divided into 3 parts as Arduino circuits, electronic circuit elements and android mobile devices. Mobile AR application was developed for android devices. In Mobile AR application, an interactive interface was designed by preparing models and objects related to experimental subjects of microcontroller course. The developed application was created on two different platforms as marker and object recognition. The platform structure of the developed mobile AR application is shown in Figure 1.

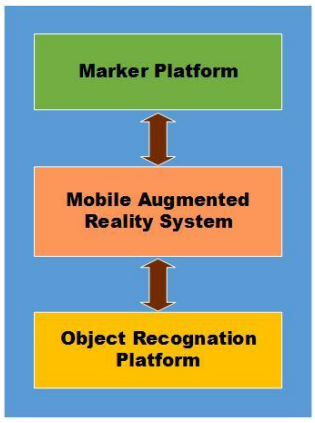



Figure 1. The structure of the mobile AR application.

In both developed platforms, technical information about the circuit components was presented to the students through a menu. The general framework of the designed application is shown in Figure 2.

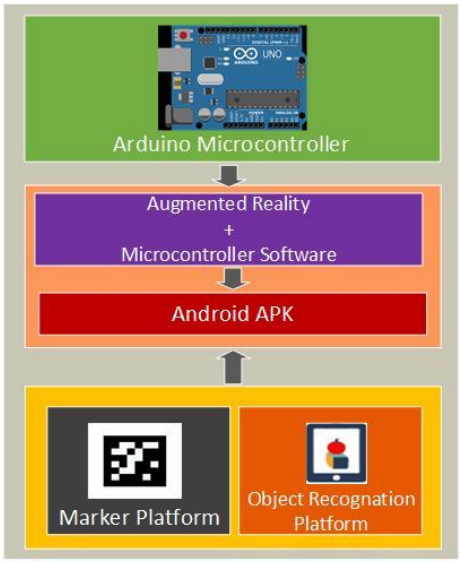



Figure 2. The general framework of the mobile AR application.

In the course of microcontroller, a few experimental applications were prepared using Arduino and electronic circuit elements for the experimental work of the students. The microcontroller software needed to provide control of the designed electronic circuitry was coded in the Arduino editor and the code was transferred to the microprocessor on the Arduino board. In order to reach the data generated by the sensors on the Arduino card, the mobile AR application was developed. The data produced by the sensors was transferred to the AR application via a Bluetooth device. An Android APK application was developed to be able to empower the mobile part of the developed AR application and seamlessly implement the Bluetooth transfer to the AR application. The mobile AR application developed for the experimental study was designed to support both the marker platform and the object recognition platform at the same time. To test the validity of the study, the students were asked a number of questions by means of the prepared survey and the results of the survey were subjected to a number of tests.

**Marker Platform**

A marker-based platform is obtained by physically adding markers to the object to which the AR operation is to be applied. Markers must have a suitable design according to the situation of the area to be used. Markers placed on real objects must have already been introduced on the system. In order for the markers to be detected quickly and easily, the positions on the real objects must be previously determined in the AR system. A successful marker should be easily and reliably detectable under all circumstances. Markers that have a proper placement angle are easily recognizable by the camera. In this way, the success of the marker-based tracking process

depends on the visibility of the marker used. In some cases, the availability of a marker-based tracking platform is not possible. There are many objects (machines, devices, etc.) that affect the trackability of the marker in the industrial environment. This causes the tracking problem in the AR system (Palmarini et al,2013). In order for AR technology to accurately present information on the real physical environment, the AR system needs information about the user's location and the point of view. Usually, the user uses a camera-enabled mobile devices to access the AR information. The AR system can show the virtual objects in the right place by determining the location and direction of the camera. In this platform, students' ability to recognize Arduino-based electronic circuits and learn about circuit elements has been tried to be developed using a marker-based learning method. First, an environment in which the experimental work is done is already prepared. In the next step, the electronic circuit and marker designed using Arduino are placed on the working environment. The process of using the application by the student consists of two steps. In the first step, the selection process is carried out using the menu in the mobile AR application. In the second step, the camera of the mobile device is brought close to an angle where the marker can be detected. Information about the purpose and design of the electronic circuit used is displayed on the mobile screen.

**Object Recognition Platform**

In the process of object detection and recognition, the steps are as follows: 1) capture a scene with a camera on a mobile device, 2) scan the captured image from the library to detect a match, 3) identify and recognize objects in the scene, and finally 4) passing the obtained result information to the user. In this method, circuitrecognition is performed in 2 steps. First, a selection operation is performed with the help of the menu for the circuit to be studied from the mobile AR application screen. In the second step, the camera of the mobile device is brought close to an angle where the marker can be detected. Object recognition is performed by this method. Information about the purpose and design of the electronic circuit used is displayed on the mobile screen. Instead of classical marker-based learning, this method focuses on the learning process by object recognition method.
The designed 3D model 1 is shown on the mobile device's screen using Eq. (1) (Zhang, 2002).

$$S = \begin{pmatrix} u \\ v \\ l \end{pmatrix} = \begin{pmatrix} f & 0 & c_x \\ 0 & f & c_y \\ 0 & 0 & 1 \end{pmatrix} (R_{3x3}\ T_{3x1}\ ) \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix} \qquad (1)$$

In the equation, s is the value of the expansion or reduction factor, and u and v are the position of the object in the screen coordinates. The variable f is the focal length, and cx and cy are the coordinates of the center of the image. These values are the internal parameter values of the camera. The external parameter values of the camera are R, 3x3 dimensional rotation matrix and T is the 3x1 dimensional camera translation matrix. The X, Y, and Z values indicate the position of the object in the real world coordinates. The internal parameters are used to calculate the camera's calibration. The external parameters represent the position and position data of a camera and have special values according to the point of view of each photograph. When the AR system is used, external parameters must be calculated.

## Finding

SPSS 17.0 was used to analyze and test the data collected from the students during the study. A survey consisting of 20 questions was applied to the students to measure and evaluate the availability of the mobile AR application. In the answer section of the survey, a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) was used. In the experimental study, the t-test and the Wilcoxon test were used to calculate the social presence and motivation values of the students.

The mobile AR application developed in this study was tested in the computer application laboratory of Necmettin Erbakan University, Seydisehir Ahmet Cengiz Faculty of Engineering. The experiment group consisted of 30 students, 7 female and 23 male students, who took microcontroller course at Necmettin Erbakan University. The students who participated in the study had no previous experience of AR. The lecturer has shown how the mobile AR application is used and the process of operation is applied to the students before the experimental work begins. The students who participated in the experimental study were asked to run the mobile AR application and to learn the electronic circuit elements without help from the course supervisor. In order to benefit from the Bluetooth support in the developed Mobile AR application, a separate Android encoding was written. The values from the temperature, humidity and light sensors on the Arduino circuit were

transferred via the Bluetooth device to the mobile AR application. Appropriate image models were created for 2these values and real time sensor values were displayed on the models.

A single marker was used for all experimental studies to avoid marker complexity in the study. In this study, image marker type was used. In this marker system, unlike barcode type markers, natural images are used as markers. Figure 3 shows an example of the use as a marker of the image used in an experimental study. We have carried out a number of process steps for marker detection respectively. In the image acquisition step, an image was provided for the marker detection process. Before to detection of the marker, a grayscale image of the system was obtained. An RGB image captured by the camera was converted to a grayscale intensity image using a conversion technique. In the designed system, the marker detection system works with a grayscale image.

In AR application, the image to be used as marker has been converted to gray scale format. After the conversion process, the graph of the histogram equalization of the image was examined. It was considered that the horizontal histogram value of the image was distributed over a wide range. Also, the image with the least vertical uctuations in the histogram was preferred. Thus, the markers placed on the picture spread over a wider area and the mobile 1 camera perceived the markers more precisely in every respect. After the experiments, the students were asked their opinions about the lessons that were done using the mobile AR application and without using it. During the use of the developed marker-based AR application, students' learning behaviors and abilities were observed. The use of the marker-based AR application in the microcontroller course is shown in Figure 3.

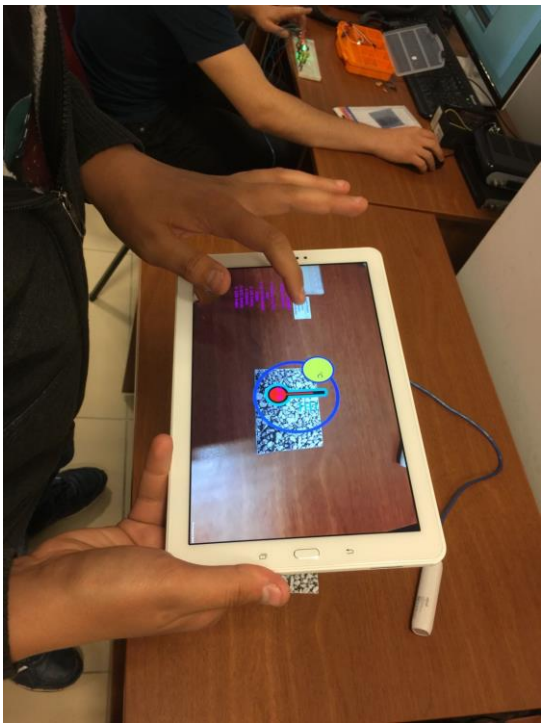


Figure 3. Marker-based mobile AR application.

In the marker-based mobile AR application, the data of the Arduino circuit can be obtained from many places in the access area of the Bluetooth device. In this process, it was considered one of the most important advantages of this platform. The students were informed about the application before using object-based mobile AR application. The learning behaviors and abilities of students were observed during the use of object recognition based mobile AR application. In this platform, students' ability to recognize Arduino-based electronic circuits and learn about circuit elements has been tried to be improved using object recognition-based learning method. In the designed system, Arduino based electronic circuits and elements are scanned using the 3D Mesh method with the help of the camera. An object database is created from the scanned objects. The use of the object recognition based AR application in the microcontroller course is shown in Figure 4.

The mobile AR application, which is based on the object recognition platform, could not be run independently of the experimental environment. The application absolutely has to detect the object. This has shown that the object recognition platform does not have the advantage of exible usability.

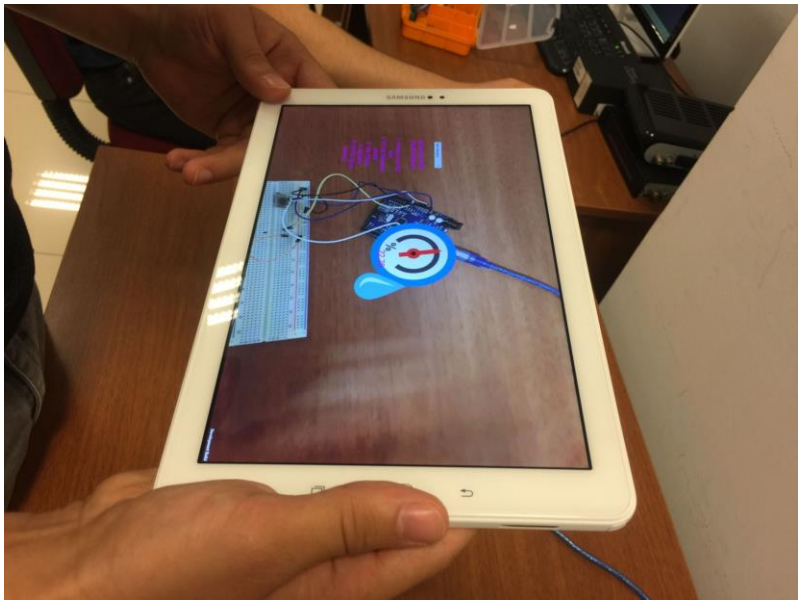
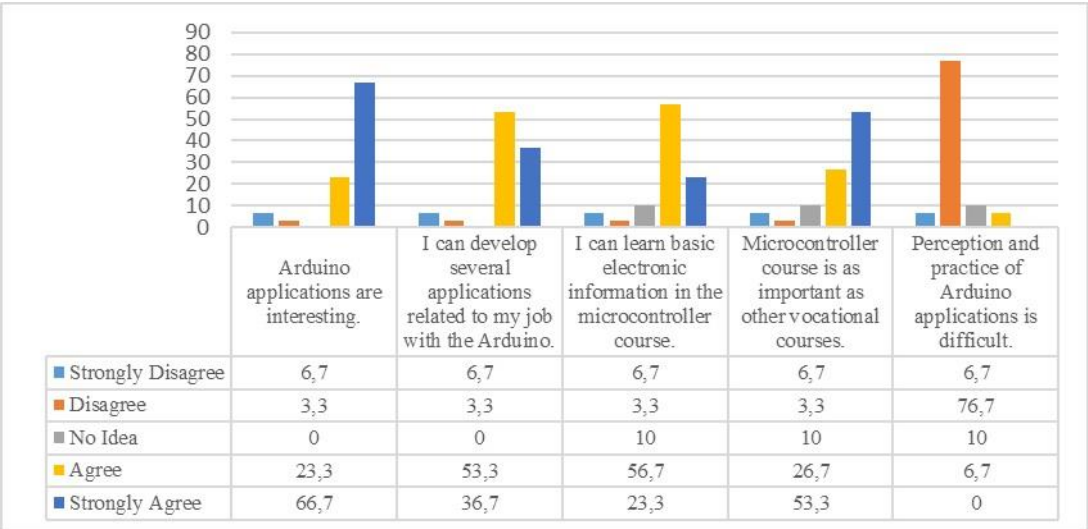


Figure 4. Object recognition based AR application.

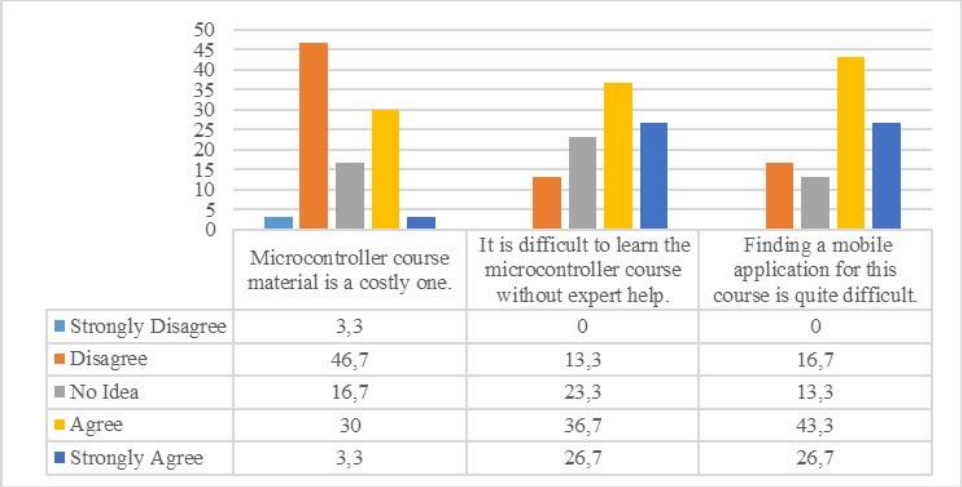
In Figure 5, the statistical and graphical results of the responses given to the survey about the importance and perception of the microcontroller course were shown. The students who did not give an opinion to the questions were not taken into consideration in the evaluation of the statistical data. It was seen that 90% of the students who participated in the experimental study showed interest in Arduino applications. It was determined that 90% of students who learned the microcontroller course developed their projects using Arduino. It was seen that 80% of the students learn basic knowledge about electronic circuit elements in microcontroller course. It has been observed that 80% of the students give importance to microcontroller course as much as other vocational courses. It was observed that 83.4% of the participants in the experimental study had the opinion that the Arduino application could be easily understood and improved.




| | Arduino applications are interesting. | I can develop several applications related to my job with the Arduino. | I can learn basic electronic information in the microcontroller course. | Microcontroller course is as important as other vocational courses. | Perception and practice of Arduino applications is difficult. |
|---|---|---|---|---|---|
| Strongly Disagree | 6,7 | 6,7 | 6,7 | 6,7 | 6,7 |
| Disagree | 3,3 | 3,3 | 3,3 | 3,3 | 76,7 |
| No Idea | 0 | 0 | 10 | 10 | 10 |
| Agree | 23,3 | 53,3 | 56,7 | 26,7 | 6,7 |
| Strongly Agree | 66,7 | 36,7 | 23,3 | 53,3 | 0 |

Figure 5. The important and learning of microcontroller course.

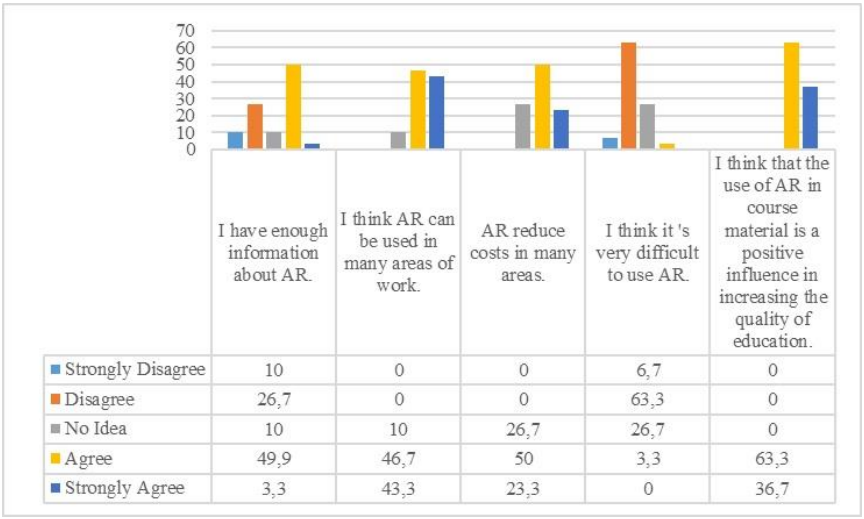
In Figure 6, the statistical and graphical results of the responses given to the survey about the cost and difficulty of the microcontroller course were shown. The students who did not give an opinion to the questions were not taken into consideration in the evaluation of the statistical data. It was observed that 50% of the students who participated in the experimental study thought that the course materials were not costly. It was found that 63.4% of the students had the opinion that the microcontroller course was difficult to learn without needing expert help. It was determined that 80% of the students thought it was difficult to find a mobile application for the microcontroller course.




| | Microcontroller course material is a costly one. | It is difficult to learn the microcontroller course without expert help. | Finding a mobile application for this course is quite difficult. |
|---|---|---|---|
| Strongly Disagree | 3,3 | 0 | 0 |
| Disagree | 46,7 | 13,3 | 16,7 |
| No Idea | 16,7 | 23,3 | 13,3 |
| Agree | 30 | 36,7 | 43,3 |
| Strongly Agree | 3,3 | 26,7 | 26,7 |

Figure 6. Cost and difficulty of the course.

In Figure 7, 1 the statistical values and graphs of the answers to the questions related to the importance and use of the AR method were shown. The students who did not give an opinion to the questions were not taken into consideration in the evaluation of the statistical data. It was determined that 53.2% of the students who participated in the experimental study had sufficient knowledge about the AR method. It was observed that 90% of the students who participated in the experimental study could use to AR method in their studies. It was seen that 73.3% of the students who participated in the experimental study thought that the AR method reduced the costs in many areas. It was determined that 70% of the students who participated in the experimental study had the idea that the use of AR was not difficult. It was observed that all of the students who participated in the experimental study thought that the education quality increased significantly by using the AR method in the course material.

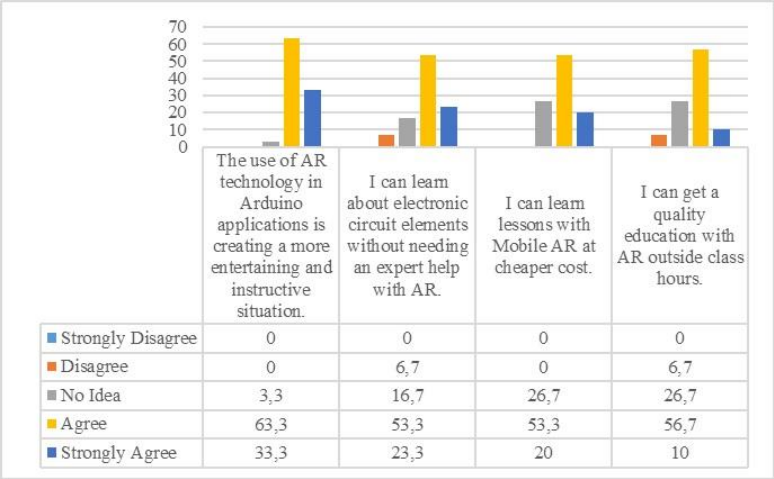



| | I have enough information about AR. | I think AR can be used in many areas of work. | AR reduce costs in many areas. | I think it 's very difficult to use AR. | I think that the use of AR in course material is a positive influence in increasing the quality of education. |
|---|---|---|---|---|---|
| Strongly Disagree | 10 | 0 | 0 | 6,7 | 0 |
| Disagree | 26,7 | 0 | 0 | 63,3 | 0 |
| No Idea | 10 | 10 | 26,7 | 26,7 | 0 |
| Agree | 49,9 | 46,7 | 50 | 3,3 | 63,3 |
| Strongly Agree | 3,3 | 43,3 | 23,3 | 0 | 36,7 |

Figure 7. Use and importance of the AR method.

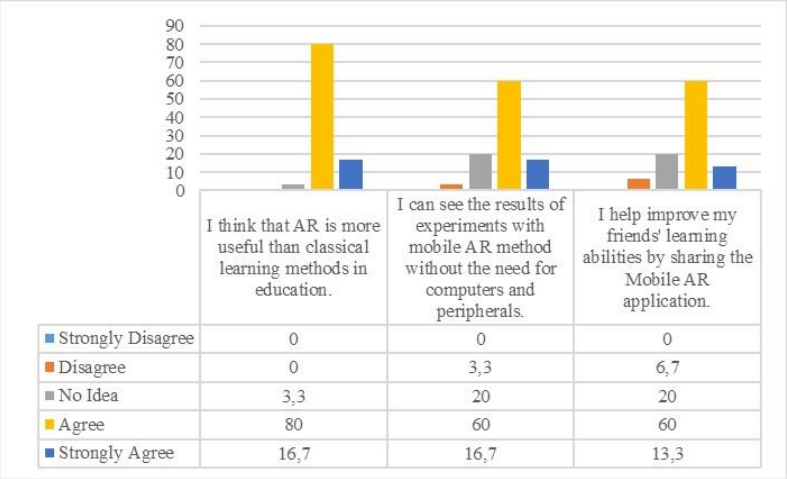
In Figure 8, the statistical values and graphs of the answers to the questions related to the educational contribution of the AR application were shown. The students who did not give an opinion to the questions were not taken into consideration in the evaluation of the statistical data. It was observed that 96.6% of the students who participated in the experimental study thought had created a more entertaining and instructive environment by using AR technology in Arduino applications. It was seen that 76.6% of the students who participated in the experimental study could learn information about electronic circuit elements without needing any expert help with AR application. It was determined that 73.3% of the students who participated in the experimental study could learn courses with mobile AR at cheaper cost. It was detected that 73.3% of the students who participated in the experimental study could learn courses with mobile AR at cheaper cost. In Figure 9, the statistical values and graphs of the answers to the questions related to the educational contribution of the mobile AR application were shown. The students who did not give an opinion to the questions were not taken into consideration in the evaluation of the statistical data. It was determined that 96.7% of the students who participated in the

experimental study thought that AR method was more effective and useful than classical learning methods in education. It was observed that 76.7% of the students who participated in the experimental study could see the experimental results of the microcontroller course with mobile AR application without the need of computers and peripherals. Analysis of the study in terms of social assets; Since the normality assumption of the dependent t-test for 30 students was violated ( t - test = 0:147; p > 0:05), a Wilcoxon test was applied to examine the importance of the study in terms of social existence. The results of Wilcoxon test showed a significant difference in terms of social presence (Z = -3:621; p < 0:05). Analysis of the study in terms of motivation; Since the normality assumption of the dependent t-test for 30 students was not violated ( t - test = 0:108; p < 0:05), the study showed a significant difference in terms of motivation.




| | The use of AR technology in Arduino applications is creating a more entertaining and instructive situation. | I can learn about electronic circuit elements without needing an expert help with AR. | I can learn lessons with Mobile AR at cheaper cost. | I can get a quality education with AR outside class hours. |
|---|---|---|---|---|
| Strongly Disagree | 0 | 0 | 0 | 0 |
| Disagree | 0 | 6,7 | 0 | 6,7 |
| No Idea | 3,3 | 16,7 | 26,7 | 26,7 |
| Agree | 63,3 | 53,3 | 53,3 | 56,7 |
| Strongly Agree | 33,3 | 23,3 | 20 | 10 |

Figure 8. Educational contribution of AR application.




| | I think that AR is more useful than classical learning methods in education. | I can see the results of experiments with mobile AR method without the need for computers and peripherals. | I help improve my friends' learning abilities by sharing the Mobile AR application. |
|---|---|---|---|
| Strongly Disagree | 0 | 0 | 0 |
| Disagree | 0 | 3,3 | 6,7 |
| No Idea | 3,3 | 20 | 20 |
| Agree | 80 | 60 | 60 |
| Strongly Agree | 16,7 | 16,7 | 13,3 |

Figure 9. Educational contribution of mobile AR application.

## Discussion

This study investigated how to improve the interactivity and availability of mobile AR application for Arduino based microcontroller courses. In the literature review, we did not encounter a Bluetooth supported AR microcontroller training on Android system. While the course contents were prepared, a more effective and interactive working environment $_{1}$ was provided by using the AR method. The improved mobile AR application allowed multiple learners to work simultaneously on a single experimental study. Students were able to get the necessary information about the experimental work quickly, without the need for expert assistance, with the help of AR mobile application. It has been seen that AR mobile application is a useful platform for dynamic content preparation and transfer of current information to end users. The developed mobile AR application was designed to be able to use both marker and object recognition platforms at the same time. One of the most important advantages of the designed application is that the user can define both markers and objects through a single mobile application. The most important feature of the marker-based recognition process in the designed mobile AR application is that the Arduino circuits used in the experimental study can be seen through a single $_{marker}$. In

the object recognition process, the Arduino circuit which will be used in the experimental work was scanned with the camera of the mobile application using the 3D mesh method. As a result of face-to-face interviews and experimental studies with students, object recognition was observed to be more useful than the marker method. It has been observed that the vast majority of students are interested in microcontroller course and Arduino applications. It has been understood that the microcontroller course can't be learned without expert help and this problem has been removed with the developed mobile AR application. The use of mobile AR application as course material provided a low cost and high efficiency training environment. In addition, an experimental study independent of the laboratory environment by use mobile AR application was performed. This study has also made an important contribution to the students' easy perception of Arduino circuits in terms of their knowledge of the material and the information about the experiment on the AR screen. The students reached the information they wanted about the experiment with the help of the designed menus very easily. As a result of this study, AR mobile application has increased its interactive learning ability in education. AR was observed that mobile learning is one of the arguments used effectively in education. As a result of the knowledge and experience gained without this study, it was concluded that similar studies should be carried out in other educational institutions as well. In this study, we have determined that the use of AR-aided learning is often beneficial to the spatial experience, practical capability and conceptual understanding of the learner, butthat more research on learning experience and learning features is needed. This study also examined the social presence and motivation of students in the microcontroller course through the use of the AR learning environment. According to the questionnaires and experimental studies, the participation of students in the course of social existence increased significantly. In a study conducted, it is stated that social presence is a fundamental characteristic of virtual practice environments(Steuer, 1992) . Jin's study showed that using the e-learning experience in the framework of students' social entities provides a significant interaction with their motivations (Jin, 2011).

## Conclusion

This study has explored whether augmented reality applications are beneficial for developing perceptual and learning skills in microcontroller education and learning. Our study demonstrates that it can benefit students by offering an interactive, interesting and original educational experience. This study provides to the current literature an experimental support for the inuence of the characteristics of interactive learning environments on the social participation and motivation of students. Experimental study results show that mobile AR application is a potential solution tool especially for non-laboratory working environments. In summary, mobile AR can improve quality and effeciency in the education sector. Using mobile AR application, students have improved their knowledge more effectively by gaining their own unique and independent learning experiences. In addition, they gain a number ı of experiences to improve communication and collaboration skills, technology use skills and social skills. In our surveys, we have identified a number of positive developments and evidence that mobile AR application developers have had the opportunity to identify their own ideas, identify new research skills, and implement them. In higher education, we have concluded that a general study on the integration and adoption of mobile AR applications is very important. We aim to expand the scope of our research on the benefits of students and best practice delivery options. For this reason, we plan to develop more interactive and effective mobile AR applications considering future technological approaches. For researchers, we suggest that there is a lot of work to be done on AR Technologies and that there is an open space for development. For researchers, research studies including problem-based and project-oriented different teaching approaches are proposed. This study does not provide a detailed explanation of the study results as no qualitative data were used. Qualitative data can be collected via face-to-face interviewsor open-ended surveys to gather more student feedback. In the future, we plan to make more interactive and realistic studies considering disabled people. We aim to move the existing AR study to mixed reality technology. We plan to increase the motivation of the participants to practice by preparing more realistic and interactive models in future work. The limitations of this work are related to the mobile AR studies limited to the field of Arduino-based Microcontroller applications. Although the work is not complicated, future research will benefit from a Bluetooth-enabled mobile AR approach that includes different curriculum frameworks. There are some restrictions in the AR system. For example, the AR system can display the enhanced image only from the viewpoints where the actual view is. For example, a user can see a virtual model from ground level by looking at the screen of the mobile device, but the scene does not look bird's eye view. To provide such visualizations, applications often complete the AR with virtual reality mode. Other limitations result from the limited capacity of the mobile devices to which the AR application is to be run. The battery consumption is very high, the memory capacities of the devices are very low and the resolution of the cameras is very low. If the level of these constraints is reduced in the future, more realistic and faster AR applications will be developed.

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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