*International Journal for Research in Vocational Education and Training (IJRVET)*
Vol. 5, Issue 1, April 2018, 1-18
DOI: 10.13152/IJRVET.5.1.1

# Effects of Augmented Reality on Student Achievement and Self-Efficacy in Vocational Education and Training

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Received: 01.05.2017; Accepted: 10.01.2018; Published: 26.04.2018

**Abstract:** This study aimed to test the impact of augmented reality (AR) use on student achievement and self-efficacy in vocational education and training. For this purpose, a marker-based AR application, called HardwareAR, was developed. HardwareAR provides information about characteristics of hardware components, ports and assembly.

The research design was quasi experimental with pre-test post-test that included a control group. The study was conducted with 46 undergraduate students in the Computer Hardware Course. Computer hardware course achievement test, motherboard assembly self-efficacy questionnaire and unstructured observation form were used in the study for data collection purposes. The control group learned the theoretical and applied information about motherboard assembly by using their textbooks (print material) while students in the experimental group used HardwareAR application for the same purpose.

It was found that the use of AR had a positive impact on student achievement in motherboard assembly whereas it had no impact on students self-efficacy related to theoretical knowledge and assembly skills. On the other hand, use of AR helped learners to complete the assembly process in a shorter time with less support.

It is concluded that compared to control group students, experimental group students were more successful in computer hardware courses. This result shows that AR application can be effective in increasing achievement. It was concluded that AR application had no effect on students motherboard assembly theoretical knowledge self-efficacy and motherboard assembly skills self-efficacy. This result may have been affected from the fact that students had high levels of theoretical knowledge and assembly skills before the implementation. Observations showed that AR application enabled students to assemble motherboard in a shorter time with less support. It is thought that simultaneous

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ISSN: 2197-8646
http://www.ijrvet.net

interaction between virtual objects and real world provided by the AR application is effective in reducing assembly time. The students who were able to see the process steps and instructions directly with the help of HardwareAR application could complete the assembly by getting less help. Considering these results, it can be argued that, thanks to simultaneous interaction it provides, AR offers an important alternative for topics that need learner application and practice.

**Keywords:** VET, Vocational Education and Training, Vocational School, Computer Assisted Instruction, Augmented Reality, Motherboard Assembly

# 1 Introduction

AR is described as a technology that integrates real images with virtual objects simultaneously (Azuma, 1997; Caudell & Mizell, 1992). In more extensive definitions, AR is defined as enhanced visualization of real images by adding virtual objects such as texts, photos, audio, animations, videos and 3-dimensional models (Delello, 2014; Perez-Lopez & Contero, 2013; Pylväs & Nokelainen, 2017). In this sense, AR provides a real and live environment. With the enhancement it offers, AR ensures that users reach more information than their sensory organs allow (Sirakaya, 2016).

Although AR has been used in other fields for a long time, it is observed that studies on the utility and potential of AR in educational environments have been recently launched (Wu et al., 2013). In addition to ease of its use; the pedagogical advantages AR offers has drawn attention to its use in education in a short time. Previous studies list the benefits provided by AR use in educational environments. It is known that while use of AR draws student interest and attention on lessons, it also increases their motivation (Delello, 2014; Perez-Lopez & Contero, 2013; Tomi & Rambli, 2013). Besides; environments that cannot be generated in real world conditions because of various impracticalities (Shelton & Hedley, 2002; Yuen et al., 2011) can be safely created and dangerous experiments (Wojciechowski & Cellary, 2013) can be safely conducted in teaching with the use of AR. Besides these features, AR has advantages such as providing student centred learning (Delello, 2014) and learning by doing (Singhal et al., 2012; Wojciechowski & Cellary, 2013). These advantages give insights about its use in applied education. In particular, the ability to provide presentation of virtual objects such as 3D models and abstract concepts by combining them with real world images makes AR an important tool for teaching assembly and maintenance tasks which requires treatment of objects (Westerfield et al., 2015).

## 1.1 Augmented Reality in Vocational Education and Training

Application skills such as assembly and maintenance are difficult to learn without individualized teaching or the supervision of the experts (Sirakaya, 2016). Assembly manuals are generally used to facilitate the assembly process (Hou et al., 2013). However, these manuals often contain very extensive and unnecessary information about assembly. The misunderstandings caused by this situation decrease the motivation of the assembler (Wang & Dunston, 2008) and result in work that takes longer (Zaeh & Wiesbeck, 2008). Generally, instructions, schemas, diagrams and videos used for this purpose are not useful for learners because they are often hard to understand and time consuming to interpret. On the other hand, users continuously have to alternate between content and the assembly while using these tools (Westerfield et al., 2015). In addition to increasing the number of errors in the assembly and assembly process, this situation also causes users to experience physical strain. AR can be used in solving of these problems with the simultaneous interaction it provides between virtual objects and the real world (Hou et al., 2013; Ke et al., 2005; Rios et al., 2013; Webel et al., 2013). Instead of following the instructions and steps they will use in the assembly from another learning material, users can see them simultaneously on the real image with the help of AR (Hou et al., 2013; Wang & Dunston, 2006; Webel et al., 2013). Thus, users can better focus on the assembly they work on without having to turn their heads or bodies to another direction (Baird, 1999; Baird & Barfield, 1999). Therefore, more intuitive, interactive and effective experiences can be provided and new opportunities can be discovered for rapid skill development (Westerfield et al., 2015). These advantages make AR a preferred technology in the fields of maintenance and assembly. There is a multitude of studies that use AR technology in the field of maintenance and assembly. Some of these studies are listed in Table 1.

Table 1 shows that use of AR in maintenance and assembly provides advantages in terms of time, number of errors and costs. Considering the contributions of AR in assembly, it could be claimed that one of the fields in which the features of AR can be effectively used is motherboard assembly. It was identified via literature review that few AR studies were conducted on motherboard assembly. In one of these studies, Alfianita (2014) developed an AR application that involved information about fundamental hardware units in the computer tower (motherboard, processor, processor fan, RAM, hard disc and power supply) and their assembly. When the application senses pre-defined markers, it presents the user with 3 dimensional videos that displays information about the hardware and how to assemble it. As a result of tests conducted on the application, Alfianita (2014) stated that the AR application is a tool that can be used in teaching hardware units.

In their studies, Baird (1999) and Baird and Barfield (1999) compared traditional teaching materials (assembly manual vs. computer assisted material) and AR imaging systems (opaque vs. see-through) in motherboard assembly. In addition to comparing wearable AR systems and traditional teaching methods, the study also focused on testing AR imaging systems with one another. Also, surveys were given to participants in each group to collect data about the usability of materials. At the end of the study, it was identified that both AR imaging systems were more effective in teaching motherboard assembly compared to the other two materials. It was also observed that students who used AR completed motherboard assembly in a shorter time period and with lesser number of errors. However, it was identified that both of these AR systems were not as adequate as traditional materials in terms of usability.

Table 1: AR Studies on Maintenance or Assembly

| **Researcher(s)** | **Assembly/ Maintenance** | **Results** |
|---|---|---|
| Caudell and Mizell (1992) | Assembly | Developed AR application for aircraft maintenance |
| Reiners, Stricker, Klinker, and Müller (1999) | Assembly | Developed AR application to be used in assembly of vehicle door lock systems |
| Sääski et al. (2008) | Assembly | Developed AR application to be used in assembly of tractor power units |
| Henderson and Feiner (2009) | Maintenance | The AR application developed to support personnel in the maintenance of armored military vehicles provided 46% more speed in maintenance time compared to the use of computer screen |
| Rios et al. (2013) | Maintenance | The AR application developed to support personnel in the maintenance of aircraft motors provided approximately 17% time saving as well as 24% increase in quality. |
| Ramírez, Mendoza, Mendoza, and González (2015) | Assembly | According to manual instructions, during statistical process control, AR use allowed the process to be 30% faster and with reduced costs. |
| Tang, Owen, Biocca, and Mou (2003) | Assembly | Use of AR in teaching assembly skills provided 82% less errors |
| Raghavan, Molineros, and Sharma (1999) | Assembly | Developed AR application to support planning engineers |
| Boud, Haniff, Baber, and Steiner (1999) | Assembly | Compared manual instructions, virtual reality and AR. The group that used AR completed the assembly the fastest. |
| Zauner, Haller, Brandl, and Hartmann (2003) | Assembly | Developed AR application to display the parts that will be used in furniture assembly in turn. |

| | | |
|---|---|---|
| Wiedenmaier, Oehme, Schmidt, and Luczak (2003) | Assembly | Compared manual instructions and AR in assembling car doors. While AR saved time in difficult assembly levels, there were no differences in easy levels. |
| Pang, Nee, Khim Ong, Yuan, and Youcef-Toumi (2006) | Assembly | Developed AR application that displays the parts to be used in assembly respectively |
| Hou et al. (2013) | Assembly | AR application in LEGO robot assembly decreased assembly time and number of errors compared to manual instructions. There were no differences in terms of cognitive load. |
| Bacca, Baldiris, Fabregat, Kinshuk, and Graf (2015) | Maintenance | AR application was used in vocational education to teach students how to paint cars. Results of the study showed that AR use increased attention, precision, trust and satisfaction. |

In a similar study, Westerfield et al. (2015) designed a smart AR system by combining AR technology and smart systems. By using AR graphics with adaptable guides, they prepared a smart AR system that displayed motherboard assembly for novice users followed by a study that compared the normal AR system with the smart AR system. According to study results, students who used the smart AR system completed motherboard assembly faster and with fewer mistakes.

Ke et al. (2005) developed a prototype AR system to be used in training students on computer hardware part repair and maintenance. As a result of their research, they stated that the prototype AR application developed for this purpose provided satisfactory results and that AR technology was an effective tool that could be used for this goal.

In their study, Seok and Kim (2008) compared print, web based and AR based assembly guides. Study results show that participants who used the AR based guide completed the motherboard assembly 60% faster than the other participants.

In his study, Sirakaya (2016) compared the assembly manual and AR application in teaching motherboard assembly. According to study results, students who learned with the help of AR application completed the motherboard assembly at 20% shorter time and with 50% less errors.

### 1.2 Significance of the Study and Hypotheses

It is thought that Computer Hardware course, which aims to provide students with information about the qualities of computer hardware units and ensure proper assembly of these units, is suitable for the use of AR technology. Computer Hardware is a course that aims to help students gain both theoretical knowledge and applied skills. In achieving the goals of the course, it is important for students to work comfortably and in a self-confident way in the assembly process. In this context, it can be argued that students' self efficacy regarding motherboard assembly can play an important role to achieve the targets of the lesson. Bandura (1986) defined self efficacy as the beliefs and ad judgment of individuals to achieve a specific task and emphasized that self efficacy is a significant factor that affects individuals' behaviors. When the concept of self efficacy is considered in terms of assembly, it can be defined as students' self judgments about the information and skills they should possess to complete the motherboard assembly. It means, students' theoretical and application skills self efficacy may play a role in accurate completion of motherboard assembly. This study attempts to identify whether the use of AR in vocational and technical education will change student self efficacy in regards to motherboard assembly.

There are many studies in literature identifying that use of AR in classes increased academic achievement (Shelton and Hedley, 2002; Sin and Zaman, 2010; Yen, Tsai and Wu, 2013; Zhang et al., 2014).while similar studies were conducted with students at different educational levels (primary, secondary and higher education), no studies were found that explored the impact of AR use in vocational and technical education on academic achievement. Students have difficulties while performing motherboard assembly due to the complex structure of hardware units and concerns related to damaging them during the process (Webel et al., 2013). Also, differences between the hardware units included in the course books and the ones used in practice make students experience confusion. The published materials that are expected to guide students during assembly of the parts are insufficient due to aforementioned reasons and negatively affect learners' development. When these are taken into consideration, it is believed that use of AR in motherboard assembly will positively contribute to students' academic achievements.

These types of studies are needed to identify the ideal use of the AR technology in educational environments. It is noteworthy that studies on the use of AR in vocational education and training are insufficient while studies were conducted in various educational fields in the literature (Bacca et al., 2014; Bacca et al., 2015). While there are some studies to develop AR applications for operators and technicians (Ramírez et al. 2015; Rios et al. 2013; Caudell and Mizell 1992; Reiners et al. 1999; Sääski et al. 2008; Henderson and Feiner 2009; Tang et al. 2003), the number of studies conducted for this purpose in educational environments is rather few. On the other hand, it was identified that studies conducted in this field used print materials as markers of the AR applications (Alfianita, 2014; Baird & Barfield, 1999; Baird, 1999; Ke et al., 2005; Seok & Kim, 2008; Sirakaya, 2016; Westerfield et al., 2015). It is believed that using the hardware units themselves (natural markers) in the process of motherboard assembly as markers is the added value of this study. It is believed that conducting the study in vocational education and training (motherboard assembly), utilizing an AR application that worked with real hardware parts and including students from a two-year program in the study will provide significant contributions to studies in this field. In this context, it was aimed to test the hypotheses provided below:

$H1_0$ = In Computer Hardware classes, there are no significant differences between academic achievements of students who learn motherboard assembly through print materials and students who learn motherboard assembly via AR applications.
$H1_1$= Computer Hardware class academic achievements of students who learn motherboard assembly via AR application are significantly higher than Computer Hardware class academic achievements of students who learn motherboard assembly through print materials.
$H2_0$= There are no significant differences between students who learn motherboard assembly through print materials and students who learn motherboard assembly via AR applications in terms of motherboard assembly theoretical knowledge self-efficacy.
$H2_1$= Motherboard assembly theoretical knowledge self-efficacy of students who learn motherboard assembly via AR applications is significantly higher than that of students who learn motherboard assembly through print materials.
$H3_0$= There are no significant differences between students who learn motherboard assembly through print materials and students who learn motherboard assembly via AR applications in terms of motherboard assembly application skills self-efficacy.
$H3_1$= Motherboard assembly application skills self-efficacy of students who learn motherboard assembly via AR applications is significantly higher than that of students who learn motherboard assembly through print materials.

## 2 Method

A quasi experimental, random matched design with pre-test post-test and control group was used in the study. This design is used in order to increase the possibility of having equal groups in terms of the studied variables (Büyüköztürk et al., 2008). For this reason, sample pairs generated according to pre-test results were randomly assigned to experimental and control groups.

### 2.1 Working Group

The study consisted of 46 (all) students (18 female, 28 male) attending their $1_{st}$ year in Computer Programming at Ahi Evran University, Mucur Vocational School of Higher Education. Each pair of students were matched according to their equivalency in academic achievement and self-efficacy results obtained in the pre-test and 23 subject pairs were obtained in this manner. Instructor views were sought about these subject pairs. 6 subject pairs were changed based on the views of the instructors in the department and it was ensured that all subject pairs were then equivalent in terms of variables such as achievement in general, prior knowledge, socioeconomic status, gender, experience and technical knowledge. Later, the students included in the subject pairs were randomly assigned to experimental and control groups to form the 23-student experimental and 23-student control groups.

## 2.2 Learning Materials (HardwareAR)

A marker-based augmented reality application called HardwareAR was developed for the implementation process. In this application, it was decided to use hardware pieces as natural markers instead of print materials in order to ensure that learners directly interact with the hardware units. For this purpose, photos of the hardware units to be used in HardwareAR were taken in a studio. Then, in order for these photos to be sensed as markers by HardwareAR, the photos were adjusted as needed with the help of Photoshop CS5 program. Thus, it was ensured that motherboard, processor, hard disc and RAM were used as markers. Unity3D game motor was used in the development of the HardwareAR application. Project file was improved by integrating the required Software Development Kits and the photographs determined as markers into Unity3D environment. AR application was developed in this environment and converted into setup file (.apk) format. The setup file was distributed to the students in experimental group before implementation and it was ensured that they installed the file in their mobile devices (smart phones). Since hardware units introduced as markers were needed to run the HardwareAR application, distributing the application did not cause any problems in terms of the validity of the study. HardwareAR application concurrently adds on the real image of the hardware part virtual data including its features, connection ports and assembly. Therefore, it was ensured that students obtained the information they needed through hardware units they were assembling rather than through another means. HardwareAR application includes theoretical and applied information that the students need about motherboard assembly. Screenshots of HardwareAR are presented in Figure 1.

## 2.3 Implementation Process

During the research process, students were both provided with theoretical information and they were given opportunities to assemble motherboards. The students included in experimental and control groups went through the same stages in the process, only the teaching material was different for each group. First of all, theoretical and applied information was provided by the instructor (2 weeks - 4 lesson hours) in the courses where motherboard assembly was going to be implemented. The related hardware units were distributed to learners in the next 2 weeks (4 lesson hours) in order for them to apply the previously provided knowledge. In this phase, the students were expected to place the processor, hard disc, RAM and the display card on the accurate parts of the motherboard.

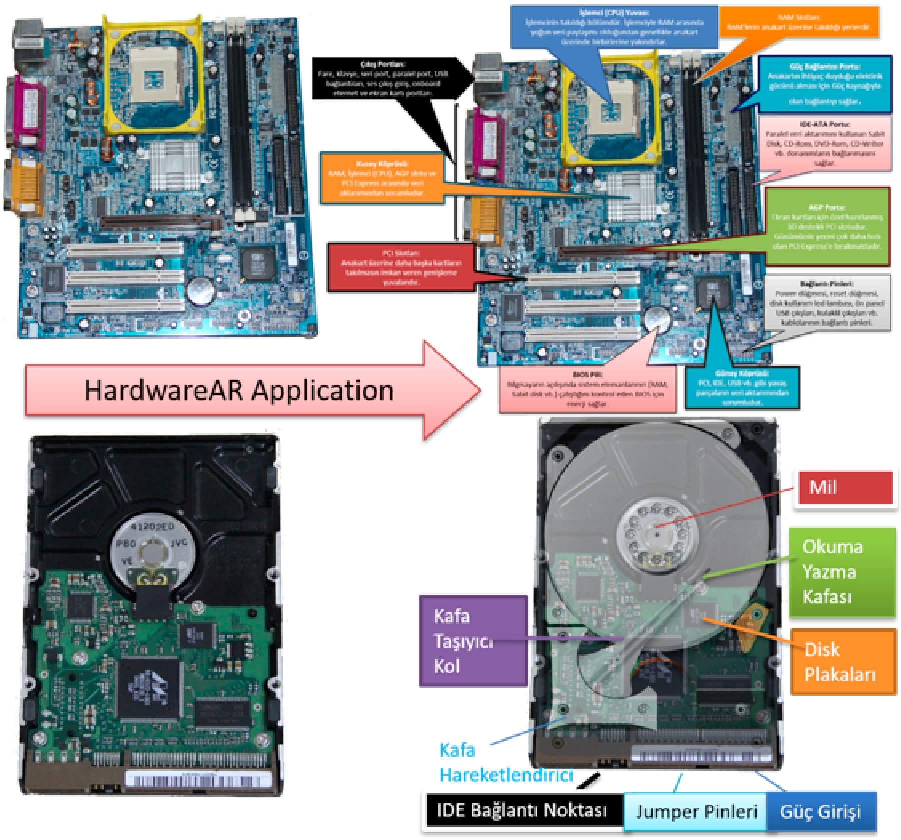


Figure 1: Screenshots of HardwareAR Application

The experimental operation was utilized in those 4 weeks and students in the experimental and control groups were taught by using different materials. The control group learned the theoretical and applied information about motherboard assembly by using their textbooks (print material) while students in the experimental group used HardwareAR application for the same purpose. Students in both groups worked individually during this process and only oral support was provided to students by the instructor. The implementation was completed in 6 weeks (12 lesson hours) with 2 weeks for implementation of the pre and post tests and 4 weeks for teaching motherboard components and its assembly in an applied manner.

### 2.4 Data Collection Tools

Computer hardware course achievement test, motherboard assembly self-efficacy questionnaire and unstructured observation form were used in the study for data collection purposes. Computer hardware course achievement test: The test aimed to identify students' knowledge levels on the functions and characteristics of the parts included in the computer tower. The achievement test developed by the researchers consisted of 20 multiple choice items. Each item in the test is scored 5 points and the lowest score that can be obtained from the test is 0 while and the highest score is 100. The test was analyzed by 2 field experts to ensure content and face validity. After the necessary adjustments were made after the expert review, pilot implementation was conducted on 48 learners who previously studied the computer hardware course. Kuder-Richardson-20 (KR-20) reliability co-efficient was calculated as 0.75 after the piloting. It can be claimed that the test has good reliability based on this value (Büyüköztürk, 2007). The achievement test was conducted twice on students; before and after motherboard assembly courses.

Motherboard assembly self-efficacy questionnaire: Since no measurement tools existed to identify students' motherboard assembly theoretical knowledge self-efficacy and motherboard assembly skill self-efficacy, a questionnaire was developed by the researchers. The 5-point Likert questionnaire consisted of 27 items in total - 16 items to identify theoretical knowledge self-efficacy and 11 items to identify assembly skills self-efficacy. These items aim to measure students' self-efficacy related to motherboard, processor, hard disc and RAM topics, included among the basic hardware units of the computer. The questionnaire items included statements on theoretical knowledge and assembly skills such as basic features, functions, types, ports and assembly of the hardware units. According to the responses given to the questionnaire, a student can obtain minimum 16 and maximum 80 in theoretical knowledge self-efficacy; minimum 11 and maximum 55 in assembly skills self-efficacy; and minimum 27 and maximum 135 in total. The questionnaire was finalized after 2 field experts analyzed it and some adjustments were made based on expert review.

Unstructured Observation Form: By observing the experimental and control groups during motherboard assembly, the researchers made notes with the help of unstructured observation form. Unstructured observation form enables the observer to be freer during data gathering (Büyüköztürk et al., 2008). Both researchers in the study observed students' motherboard assembly process and made notes without any interventions in their role as observers-as-participant.

## 2.5 Data Analysis

Since the sample size is less than 50, Shapiro-Wilks test was used to see whether the tests had a normal distribution (Büyüköztürk, 2007). Also, graphic analysis was done by drawing normal distribution curve. Although the tests showed normal distribution based on analysis results, it was decided to use non-parametric tests since the number of members in experimental and control groups was less than 30 (Roscoe, 1975; cited by Büyüköztürk et.al, 2008). Therefore, Mann Whitney U-test was utilized to identify whether experimental and control groups had significant differences in achievement and self-efficacy.

# 3 Findings

## 3.1 Findings about Group Equivalence before Implementation

Mann Whitney U-Test was conducted to determine whether the learners who were placed in experimental or control groups significantly differed in terms of study variables. Data related to test results are provided in Table 2.

Table 2: U-Test Results for Groups before Implementation: Achievement, Theoretical. TK=Theoretical Knowledge, AS=Assembly Skills

| Variable | Group | n | X | Sd | Mean Rank | Rank Sum | U Value | z | p |
|---|---|---|---|---|---|---|---|---|---|
| **Achievement** | Exp. | 23 | 58,3 | 3,12 | 24,09 | 554 | 251 | -0,3 | 0,77 |
| | Contr. | 23 | 57,4 | 3,48 | 22,91 | 527 | | | |
| **TK self-efficacy** | Exp. | 23 | 55,6 | 2,36 | 24,67 | 567,5 | 237,5 | -0,6 | 0,55 |
| | Contr. | 23 | 52,4 | 1,7 | 22,33 | 513 | | | |
| **AS self-efficacy** | Exp. | 23 | 42 | 1,54 | 26,11 | 600,5 | 204,5 | -1,3 | 0,19 |
| | Contr. | 23 | 39,1 | 1,42 | 20,89 | 480,5 | | | |

Table 2 shows is no significant differences between experimental and control group students' achievement (U=251, p>.05), theoretical knowledge self-efficacy (U=237.50, p>.05) and computer hardware assembly skills self-efficacy (U=204.50, p>.05) before implementation. This finding shows that experiment and control groups were equal before implementation in terms of research variables.

## 3.2 The Influence of AR Application on Achievement

Mann Whitney U-Test was conducted to determine whether learners' achievement levels significantly differed according to posttest results. Data related to the results are provided in Table 3.

Table 3: U-test Results for Achievement Based on Group

| Group | n | $\bar{X}$ | Sd | Mean Rank | Rank Sum | U Value | z | p |
|---|---|---|---|---|---|---|---|---|
| **Experimental** | 23 | 67,61 | 2,77 | 27,87 | 641 | 164 | -2,221 | ,026 |
| **Control** | 23 | 57,39 | 3,29 | 19,13 | 440 | | | |

Table 3 points to a significant difference in achievement between the experimental group which took the courses with AR application and the control group which used the assembly manual (U=164, p<.05). When mean ranks are taken into consideration, it is observed that the students who took courses with AR application were more successful than the students that used the assembly manual. This finding can be interpreted that AR application has a positive contribution in increasing student achievement.

## 3.3 Influence of AR Application on Theoretical Knowledge Self-Efficacy

Mann Whitney U-Test was conducted to determine whether learners' theoretical knowledge self-efficacy levels significantly differed according to posttest results. Data related to the results are provided in Table 4.

Table 4: U-test Results for Achievement Based on Group

| Group | n | $\bar{X}$ | Sd | Mean Rank | Rank Sum | U Value | z | p |
|---|---|---|---|---|---|---|---|---|
| **Experimental** | 23 | 61,78 | 1,92 | 25,67 | 590,50 | 214,50 | -1,100 | ,272 |
| **Control** | 23 | 59,22 | 1,97 | 21,33 | 490,50 | | | |

First of all, Table 4 shows that students in the experimental and control groups had a high level of theoretical knowledge self-efficacy. Also no significant differences were observed between experimental group students who took the courses with AR application and the control group students who used the assembly manual (U=214.50, p>.05). The finding can be interpreted that AR application had no effect on students' theoretical knowledge self-efficacy.

## 3.4 Influence of AR Application on Assembly Skills Self-Efficacy

Mann Whitney U-Test was conducted to determine whether learners' assembly skills self-efficacy levels significantly differed according to posttest results. Data related to the results are provided in Table 5.

Table 5: U-test Results for Achievement Based on Group

| Group | n | $\bar{X}$ | Sd | Mean Rank | Rank Sum | U Value | z | p |
|---|---|---|---|---|---|---|---|---|
| **Experimental** | 23 | 45,65 | 1,14 | 24,50 | 563,50 | 241,50 | -.507 | .612 |
| **Control** | 23 | 44,61 | 1,51 | 22,50 | 517,50 | | | |

First of all, Table 5 shows that students in the experimental and control groups had a high level of assembly skills self-efficacy. Also no significant differences were observed between experimental group students who took the courses with AR application and the control group students who used the assembly manual ($U=241.50$, $p>.05$). The finding can be interpreted that AR application had no effect on students' assembly skills self-efficacy.

### 3.5 Findings Related to Researchers' Field Notes

Based on researchers' observations, it was identified that experimental group students who took the courses with AR application completed the motherboard assembly in a shorter time. This finding was based on the notes taken by the researchers that while motherboard assembly was completed by the experimental group in class periods, control group had to be given extra time to complete their task. It was also observed that students in the experimental group asked for help from their friends or their instructor much less compared to students in the control group.

## 4 Results and Discussion

Based on the analyses conducted in the frame word of this study, it is concluded that compared to control group students, experimental group students were more successful in computer hardware courses. This result shows that AR application can be effective in increasing achievement. It has also been concluded in many studies that AR use in educational environments increases learner achievement (Shelton & Hedley, 2002; Sin & Zaman, 2010; Yen et al., 2013; Zhang et al., 2014). When contributions provided by AR technology in educational environments are taken into consideration, it can be argued that this result is expected. It is known that AR technology draws student interest and attention into courses and increases student motivation (Delello, 2014; Perez-Lopez & Contero, 2013; Tomi & Rambli, 2013). With these aspects, AR may have contributed to student achievement in the experimental group. Another finding of this study shows that AR application had no effect on students' motherboard assembly theoretical knowledge self-efficacy. Based on the analyses, it was identified that although theoretical knowledge self-efficacy of experimental group students increased, the increase was not significant. This result is parallel to the results obtained in other studies which state that the use of augmented reality does not change the students' computer self-efficacy or their attitudes towards computers (İbili & Şahin, 2015b; İbili & Şahin, 2015a). This result may have been affected from the fact that students had higher levels of theoretical knowledge self-efficacy before the implementation. Mentioning a similar finding, Hou et al. (2013) stated that AR use proves to be more effective especially in novice assemblers. Since self-efficacy is a concept which develops in time and with experiences (İbili & Şahin, 2015a), this result may be regarded to be based on the insufficiency of a 6-week implementation process in the formation of a significant difference. It was concluded that AR application had no effect on learners' motherboard assembly skills self-efficacy. This result may have been affected from the fact that students had higher levels of assembly skills before the implementation. The department students attended may have affected this outcome. This finding contradicts the findings of various studies which stated that AR technology helps learners to assemble main boards faster and with fewer mistakes (Baird, 1999; Baird & Barfield, 1999; Seok & Kim, 2008; Sirakaya, 2016; Westerfield et al., 2015). Similarly, Bacca et al., (2015) reported that AR use has positive effects on students' application skills. Observations showed that AR application enabled students to assemble motherboard in a shorter time. This result is supported by other studies in the literature (Baird, 1999; Baird & Barfield, 1999; Seok & Kim, 2008; Sirakaya, 2016; Westerfield et al., 2015). Similarly, it was concluded in studies undertaken in other fields that AR use increased operators' and workers' maintenance and assembly speed (Boud et al., 1999; Henderson & Feiner, 2009; Hou et al., 2013; Ramírez et al., 2015; Rios et al., 2013; Tang et al., 2003). It is thought that simultaneous interaction between virtual objects and real world provided by the AR application is effective in reducing assembly time. Thus, students in this study were able to see the assembly steps directly on the hardware parts themselves rather than studying them on another teaching material. Another finding points to the fact that the students using AR application asked for less help from their instructors or friends. The students who were able to see the process steps and instructions directly with the help of HardwareAR application could complete the assembly by getting less help. Considering these results, it can be argued that, thanks to simultaneous interaction it provides, AR offers an important alternative for topics that need learner application and practice. AR technology which is used by technicians in different sectors such as repair, maintenance and assembly is an effective tool that can be used in educational environments for applied subjects.

## 5 Conclusion and Suggestions

This study presented the effects of AR use in vocational education and training on student achievement and self-efficacy. The results show that while AR use increases student achievement, it has no effect on theoretical knowledge self-efficacy and assembly skills self-efficacy. It was also understood that AR use decreases the duration for motherboard assembly and it enables students to work with less help. As a result, it can be stated that the applications developed with AR technology can be used as effective tools in applied courses. Considering the results obtained in this study, following suggestions are offered to guide researchers and application developers in future AR studies:

- It was concluded in the study that AR use increased student achievement. Based on this point, new studies can be planned in different fields and by using different sample levels.
- Student' smart phones were used in this study. Although no problems were experienced in the use of these devices, due to their nature, they have limitations based on small screen sizes. Therefore, more appropriate devices for applications such as AR goggles can be used in future studies by receiving necessary support from related institutions.

- The study carried out in the computer hardware course can be replicated in different courses in which students engage in applied work.
- The study was carried out with Vocational School of Higher Education students. Similar studies can be carried out with different sample groups in educational institutions such as Vocational High Schools etc. in which applied teaching is extensively used.

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