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Are Reality, Simulation, and Augmented Reality Interchangeable?

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Abstract

Students often ask why they should learn or where they would use this knowledge when learning. Real-life experiences make learning more meaningful for the students. Thus, learning environments where the students could acquire real-life experiences are important. However, due to the student profile, crowded classes, inadequate course hours, technological advances, natural disasters, etc., conventional instruction methods could not meet student requirements and they could not practice. This negatively affects learning achievements and psychomotor skills of the students. Effective real-life educational experiences are required to improve learning achievements and psychomotor skills of the students. Thus, the present study aimed to investigate learning achievement and psychomotor skills levels of college students in the ICT course and substitution of augmented reality applications and simulations with real-life experiences. The study data were collected from 63 college students. Descriptive statistics, two-way ANOVA, and Wilcoxon Signed Rank Test analysis were employed to answer the research questions. The findings demonstrated that augmented reality and simulation-assisted learning environments were as effective as real-life learning environments in the improvement of the learning achievements and psychomotor skills of the students in the ICT course. Thus, it could be suggested that augmented reality or simulation applications could be employed in learning environments that lack real-life experiences.

Keywords: Reality, Augmented reality, Improving classroom teaching, Simulations, Achievement

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Introduction

Learning is a process where knowledge is construction via transformation of experiences. The most effective factor in learning is not the storage of knowledge but the production of new knowledge with real-life experiences. The most permanent, effective and concrete learning is acquired through real-life experiences. Real-life experiences are the foundation of future experiences and learning. Individuals make sense of and learn from their experiences, and could analyze the outcomes of learning (Morris, 2020). Real-life experiences support permanent learning and contribute to the learning of each student to the extent of personal skills (Yalın, 2015: 123). Furthermore, it could facilitate observation and research of the students (Cited by Musyaddad & Suyanto, 2019), and improve their creativity and enthusiasm for learning (Kiewra & Veselack, 2016). An adequate learning environment where students could reinforce acquired knowledge and learn from the pedagogical approach is important (Chiu, 2019). The association of the learning environment with the real world would lead to real-life experiences. Students experience the sensory properties of objects in these environments and become familiar with the environment (Zacharia & Olympiou, 2011). Thus, they could achieve predetermined objectives easily. In these environments, students could develop their conceptual comprehension (Chiu, 2019; Morris, 2020) and apply acquired knowledge and skills in different real-life conditions. Real-life experiences include in-classroom (models, real objects, etc.) and out-of-classroom activities (laboratory applications, internships, exchange programs, field studies, case studies, virtual learning environments, in-service training) where students work individually or as a team under the supervision of an instructor.

Real-life experiences play a key role in the Information and Communication Technologies (ICT) course. ICT course could improve the quality of education. Previous studies emphasized that the ICT course could facilitate the development of higher cognitive skills such as analysis and evaluation (Claro et al., 2012). The ICT course includes theoretical (knowledge) and practical (real-life experiences) education (de Brock, 2001). Theoretical education aims at the acquisition of knowledge-comprehension where the content is instructed with conventional or various methods. In practical education, students could experience real-life and use material objects (computer parts such as motherboards, processors, etc.) in the learning environment. It aims the acquisition of psychomotor skills. When compared to theoretical education, applied education conducted with equipment could improve inquiry, problem-solving skills of the students, allow them to experience challenges and explore the nature of science (De et al., 2013). However, due to various factors (individual differences, crowded classrooms, lack of required material, costs, learning environment problems, etc.), students could not acquire real-life experiences since they could not apply learned knowledge, leading to inadequate ICT education, adversely affecting learning achievements and psychomotor skills. Although the ICT course aims to contribute to the professional skills of the students, it was reported that several students could not acquire the targeted skills (Akkoyunlu & Kurbanoğlu, 2003). Similarly, certain studies (Topu & Göktaş, 2012;) reported that college students considered the ICT course inadequate and stated that available hardware were inadequate. Thus, solutions that could lead to real-life experiences are important for the students. There is a need for alternative learning environments that would lead to real-life experiences in the ICT course based on student requirements and positive learning outcomes (similar to real-life learning environments).

AR and SM in Education

Various technological solutions that employ different learning methodologies are available to support education (Moro et al., 2021). The integration of technologies with education is important to ensure that every student could practice, to improve learning environments and student participation (Sahin & Yılmaz, 2020). The employment of projectors, computers, and other technical equipment in the classroom could lead to fun and enjoyable learning (Haleem et al., 2022). New classroom technologies allow the students to diversify knowledge construction methods (Sampaio, & Almeida, 2016) and analyze their interests in a broader context by exposing them to real-life experiences. To ensure successful learning, knowledge, and practice should be instructed in real or realistic environments (Koçyiğit, 2011). Solutions such as virtual 3D, intelligent tutor systems, immersive worlds, simulations, and augmented reality are particularly adequate for hands-on training (Moro et al., 2021).

For example, it was reported that simulated learning environments could be developed to support laboratory work and improve student access to education and educational opportunities (Alfred et al., 2018). Virtual reality simulations could be an alternative to real-life experiences by turning them into virtual manipulatives (Moyer et al., 2002). Thus, learning environments that included simulation and augmented reality technologies (including concrete objects and 3D simulations) were designed in the present study.

Simulations are computer applications employed to animate events that could not be conducted in daily life due to various factors, where individuals take responsibility for, were designed to achieve a specific objective, and reflect reality (Babur, 2016). These were generally described as an imitation of a process or situation (Rooney & Nyström, 2018). Conventional instruction could be successfully developed with computer simulations (Rutten et al., 2012). Studies demonstrated that educational simulations were constructive in learning outcomes (Almasri, 2022; Matute-Vallejo & Melero-Polo, 2019, Sanina et al., 2020; Vlachopoulos & Makri, 2017). Simulations allow students to learn at their own pace and proficiency, leading to more efficient learning (Henderson et al., 2017; Kim et al., 2013). They allow them to improve their skills without exposure to situations with negative financial or ethical consequences (Almasri, 2022). They do not only increase student participation and motivation to construct new knowledge, but also facilitate comprehension of the course content (Lindgren et al., 2016). Although various types of simulations (Deterministic and Probabilistic, Time Dependent and Time Independent, Games, Virtual interactive etc.) are available, computer simulations that run on desktop or laptop computers with mouse and keyboard controls were employed in the current study.

Augmented reality (AR), another technology employed in the study, allows human-computer interaction (Azuma et al., 2001). It allows individuals to interact within a real environment by superimposing pre-recorded virtual data on the environment. Technically, AR takes the image of the real objects with a camera, adds virtual objects at predetermined locations, and combines the real and virtual worlds (Azuma et al., 2001; Cai et al., 2014; Milgram & Kishino, 1994;). Thus, it alters the way individuals interact with the real world. The effectiveness of AR has been investigated in almost every field, including entertainment, business, health, tourism, military, manufacturing and education industries. AR has been employed in the design of pedagogical tools that would improve learning and instruction experiences in education (Garzón et al., 2017). Several studies reported that AR allowed students to acquire more meaningful knowledge and helped them develop special skills that were more difficult to acquire with other pedagogical tools (Akçayir & Akçayir, 2017; Safar, 2016). It is a powerful technology that supports education, especially in industrial service procedures (Webel et al., 2011). AR learning environments have a positive effect on educational outcomes such as learning achievements, attitudes, motivation, interest, and retention (Akçayır & Akçayır, 2017; Garzón et al., 2019; Kucuk Avci et al., 2019). AR leads to flexibility in learning in an interactive environment that could be adapted to the real world (Barsom et al., 2016). A well-designed AR environment could improve awareness about the real world and learning (Wu et al., 2018). Based on the advantages and strengths of AR, it could be suggested that it could be one of the most promising tools in education.

There are several studies on simulation and AR in the literature. Lichti and Roth (2018) investigated the impact of computer-based simulations or concrete objects in learning environments on functional thinking skills of sixth graders. Although both environments led to significant increases in functional thinking skills, the increase in the simulation group was higher. The study findings demonstrated that computer-based simulation was superior to learning environments that employed concrete objects in the development of functional thinking skills. Evangelou and Kotsis (2019) compared conceptual comprehension of friction force in a study conducted with concrete objects and simulation. They reported no significant difference in conceptual comprehension between the students who conducted virtual friction force experiments and those who conducted real-world experiments. Zendler and Greiner (2020) compared the empirical method and simulation based on various learning outcomes in chemistry education. They determined that both groups exhibited similar observation and application knowledge performances. Furthermore, the authors designated simulation and empirical methods as complementary instructional methods. Krüger et al., (2022) observed the effects of applied experimentation and interactive computer simulation in science education on secondary school students' learning achievements, contextual interests, and cognitive loads. It was determined that despite the high cognitive load, the students who conducted simulations exhibited higher learning achievements when compared to the students who conducted experiments. However, the contextual interest levels of the experimenters were higher when compared to those who simulated. It was also emphasized that simulations could be suitable for the instruction of complex topics, and both methods could be used to complement the weaknesses of the other. Similarly, in a study where conventional and simulation-based instruction methods were compared, the visuals did not provide better learning, but complementary use of both conventional instruction and computer simulations could improve education (Rutten et al., 2012).

The review of the studies on AR demonstrated that Hsiao et al., (2012) quantitatively compared student achievements and attitudes in three learning environments, including AR, simulation-based, and conventional face-to-face instruction of the ecosystems. The study findings demonstrated that there were no differences between the three learning environments based on student learning achievements. On the other hand, since the students in the AR group had higher attitude scores when compared to the other groups, the students perceived the AR environment as more beneficial when compared to the other two. Chang and Hwang (2018) compared AR-based flipped learning and conventional learning in a study conducted with primary school students. The empirical findings revealed that the AR-based flipped learning approach improved the learning motivation, critical thinking skills and group self-efficacy, and increased student performance in projects. Chang et al., (2016) compared augmented reality and interactive simulation technologies to support learning in social sciences. The study findings demonstrated that there were no significant differences in knowledge and attitudes; however, a significant difference was determined that favored AR in perceptions. Hsiao et al., (2016) compared mobile AR and multimedia instruction in a natural science course. The study reported that AR had a significant positive impact on academic achievements and motivation of the students when compared to multimedia instruction. Also, certain studies compared AR and virtual reality or mixed reality. However, these were not included in the study since these were out of the scope of the present study.

Studies demonstrated that the effectiveness of AR and simulation-based learning environments varied based on the study group, discipline, content, and research variables. Studies generally investigated achievements, motivation, attitudes, and cognitive load in science, physics, chemistry, and mathematics courses. In contrast, the present study focused on alternative solutions that could improve learning achievements and psychomotor skills of the students, similar to learning environments that provide real-life experiences. Furthermore, further studies are required to determine effective educational technologies in different conditions (Chang et al., 2016). The present study is unique in the sense that three learning environments (AR, simulation, and real-life experiences) were compared. The study was conducted based on the requirements reported in the literature and aimed to investigate the effects of learning environments (AR, simulation, and real-life experiences) on learning achievements and psychomotor skills of college students. Thus, the following research questions were determined.

1) Can AR and simulation be used to replace real-life experiences in terms of learning achievements?
2) Can AR and simulation be used to replace real-life experiences in terms of psychomotor skills?

Method

Research Model

The present study was conducted with a quasi-experimental design, a quantitative research method. In cases where experimental and control groups could not be assigned randomly, a quasi-experimental design is employed and groups are assigned based on existing classes (Fraenkel & Wallen, 2000; McMillan & Schumacher, 2010). The research model is presented in Figure 1.

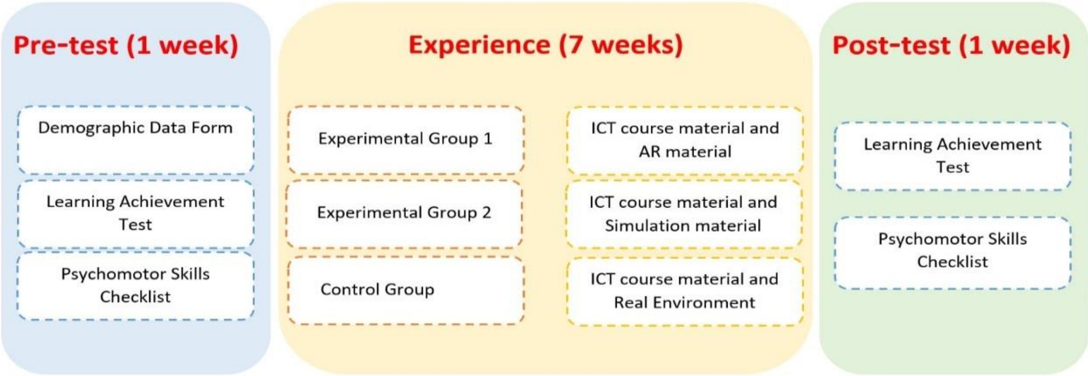

Figure 1. The Research Model

As seen in Fig 1, the research model included three parts and the study was completed in 9 weeks. Before the experience, a demographic data form, psychomotor skills checklist, and learning achievement test were applied to each group as a pre-test (1 week). During the experimental process, the same ICT course was instructed to each group (2 hours a week, by the same instructor, with the same course material), but different materials were used during the practice hour. After the instruction with the ICT course material, the practice session was conducted with AR material in Experimental Group 1, simulation material in Experimental Group 2, and with real objects (real-life experience) in the Control group (7 weeks). At the end of the experience, psychomotor skills checklist and learning achievement test were applied as a post-test (1 week).

Participants

The study data were collected from 63 associate degree students attending a public university. The participants were assigned with the convenience sampling method. Convenience sampling method allows fast and easy assignment of the sample (Patton, 2014). The demographic characteristics of the participants are presented in Table 1.

Table 1.

Demographic Characteristics of the Participants

Demographics		Count (N)	Percentage (%)
Gender	Male	39	61.9
	Female	24	38.1
Age	18-19	42	66.6
	20-21	18	28.5
	22-29	3	4.7
ICT course experience	Yes	42	66.6
	No	21	33.3
Smartphone or tablet ownership	Yes	59	93.6
	No	4	6.4

As seen in Table 1, 39 (61.9%) participants were male, and 24 (38.1%) were female. Most participants were 18 or 19 years old (N = 42, 66.6%), and 18 were 20 or 21 (21.5%), and only three (4.7%) were 22 or older. Two-third of the participants (N = 42, 66.6%) had taken an ICT course before, and one-third of the participants (N = 21, 33.3%) did not. Fifty-nine (93.6%) participants owned a smartphone, and only four (6.4%) participants did not. The participants were divided into three groups: 2 experimental (augmented reality (AR) and simulation (SM)) and 1 control (Real-Experience (RE)) groups. The participants were assigned to these groups based on 3 criteria (CR) presented in Figure 2.

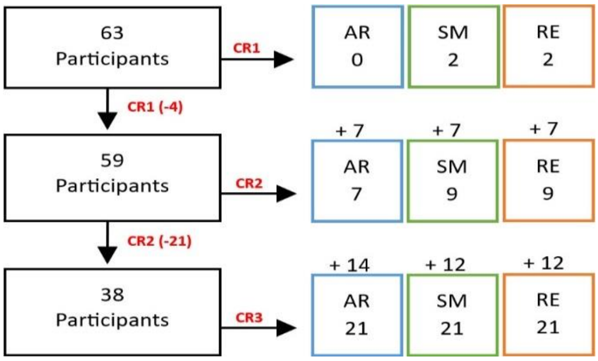

Figure 2. Sample assignment strategy

1st.CR *Based on smart mobile phone ownership*: The students had to own a smartphone or a tablet to use the AR material. Thus, basic demographic data were analyzed (the question was included in the form) to determine the participants without a smartphone, or a tablet. There were 4 participants who did not own a smartphone. 2 were randomly assigned to the RE group, and the remaining 2 were assigned to the SM group.

2nd.CR *Based on ICT course experience*: 21 of the remaining 59 participants, who did not take the ICT course, were equally distributed into 3 groups.

3rd.CR *Based on Learning Achievement pre-test scores*: The Learning Achievement test was applied to determine the statistical equivalence of the groups. Students were ranked based on the learning achievement scores. The score ranges were determined based on the "Regulation on Associate and Undergraduate Education and Evaluation". According to the regulation, students should score at least 50 to be successful. Participants were randomly assigned to groups. The score ranges formed as a result of matching scores are presented in Table 2.

Table 2.
Score Ranges of Groups

Score	AR Group		SM Group		RE Group		Total	
	N	%	N	%	N	%e	N	%
0-49	3	14.2	3	14.2	3	14.2	9	14.2
50-83	12	57.1	12	57.14	12	57.14	36	57.1
84-100	6	28.5	6	28.5	6	28.5	18	28.5
Total	21	33.3	21	33.3	21	33.3	63	100

As seen in Table 2, 9 (14.2%) participants scored between 0 and 49 (3 participants in each group), 36 (57.1%) scored between 50 and 83 (12 participants in each group), and the remaining 18 (28.5%) scored between 84 and 100 (6 participants in each group). Then, one-way analysis of variance (ANOVA) was employed to compare the equivalent between the groups. The results are presented in Table 3.

Table 3.
Equivalence of the Groups

Group	Sum of squares	sd	Mean square	F	p
Between Groups	3.55	2	1.77	.007	.993*
Within Groups	16144.7	60	269.07		
Total	16148.3	62			

ANOVA results demonstrated that there were no significant differences between learning achievement scores of the groups ($F_{(2,60)}$= .007; p<.05). This finding implied that the groups were similar equivalent to the learning achievement scores. Post-assignment group demographics are presented in Table 4.

Table 4.
Post-Assignment Group Demographics

Demographics		AR Group N	AR Group %	SM Group N	SM Group %	RE Group N	RE Group %	Total N	Total %
Gender	Female	5	23.8	11	52.3	8	38.1	24	38.1
	Male	16	76.1	10	47.6	13	61.9	39	61.9
Total		21	100	21	100	21	100	63	100

As seen in Table 4, in the AR (21) group 5 (23.8%) participants were female and 16 (76.1%) were male. In the SM (21) group, 11 (52.3%) were female and 10 (47.6%) were male. In the RE (21) group, 8 (38.1%) were female and 13 (61.9%) were male. The groups' pre-test scores (learning accomplishment and psychomotor performance pre-test) were compared, and they were determined to be equal.

Experimental procedure design

The experimental procedure is presented in Table 5. The design of both the experimental procedure and each material is addressed. As seen in Table 5, the experimental procedure was conducted over 9 weeks. In the first week, the demographic data form, learning achievement test, and psychomotor skills checklist were applied to each participant as a pre-test. ICT course instruction was conducted theoretically and practically. In theoretical instruction, the topics were instructed to all three groups with the same method (by the same instructor, using the same course material, with the presentation method). In practical instruction, the same instructor used different material in each group (AR material in the AR group, SM material in the SM group, and real objects in the RE group) to acquire real-life experiences. This process lasted for 7 weeks. On the ninth week, the learning achievement test and psychomotor skills checklist were applied to each participant as the post-test.

Table 5.
Experimental Procedure

1st Week **Pre-test**
(Demographic Information Form, Learning Achievement Test, and the Psychomotor Skills Checklist)

Weeks	Topics	Learning Outcomes: Theoretical	Learning Outcomes: Practical	Teaching Method	Materials by Group: AR	Materials by Group: SM	Materials by Group: RE
2	CPU	Could explain the task of the processor cache. Could identify the processor at once.	Could assembly the processor on the motherboard at once. Could disassembly the processor from the motherboard at once.	Explanatory instruction with **course material** (PowerPoint presentation)	AR Material	SM Material	Real Environment with real objects
3	RAM	Knows that RAM is a temporary memory. Has the knowledge to install RAM. Deducts the reasons for RAM errors. Recognizes the RAM memory at once. Deducts the reasons for hard disk errors.	Could assembly the RAM on the motherboard at once. Could disassembly the RAM from the motherboard at once.				
4	Hard Disk	Deducts the reasons for hard disk errors. Recognizes the hard disc at once.	Could assembly the hard disk in the computer case at once. Could disassembly the hard disk in the computer case at once.				

Table 5 continuing

5	Graphics Card	Knows the functions of the graphics card. Could list the steps of mounting the graphics card without error. Recognizes the graphics card at once.	Could assembly the graphics card on the motherboard at once. Could disassembly the graphics card from the motherboard at once.
6	Sound Card	Could list the steps of sound card assembly steps without error. Recognizes the sound card at once.	Could assembly the sound card on the motherboard at once. Could disassembly the sound card from the motherboard at once.
7	Network Card	Could list the network card assembly steps without error. Recognizes the network card at once.	Could assembly the network card on the motherboard at once. Could disassembly the network card from the motherboard at once.
	Power Supply	Knows the functions of the power supply. Recognizes the power supply at once.	Could assembly the power supply in the computer case at once. Could disassembly the power supply from the computer case at once.
8	Motherboard	Knows the functions of BIOS. Knows the integrated motherboard circuit. Recognizes the motherboard at once. Recognizes the motherboard parts.	Could assembly the motherboard in the computer case at once. Could disassembly the motherboard from the computer case at once.
9th Week **Post-test** (Learning Achievement Test, and Psychomotor Skills Checklist)			

Course material and real environment design

Course material was an audio, visual and textual presentation file employed to instruct the topic. The "A+ Computer Technical Staff Training" file was developed by the Cizgi Technology Research and Development Center (Cizgi TAGEM) based on the CompTIA A+ curriculum. To determine the adequacy of the course material for course objectives, an analysis form was developed and submitted to three faculty members (at the Department of Computer and Instructional Technologies Education) who had instructed the ICT course before. Based on their comments, it was determined that the material was adequate for course achievements. The course material was presented in Figure 3.

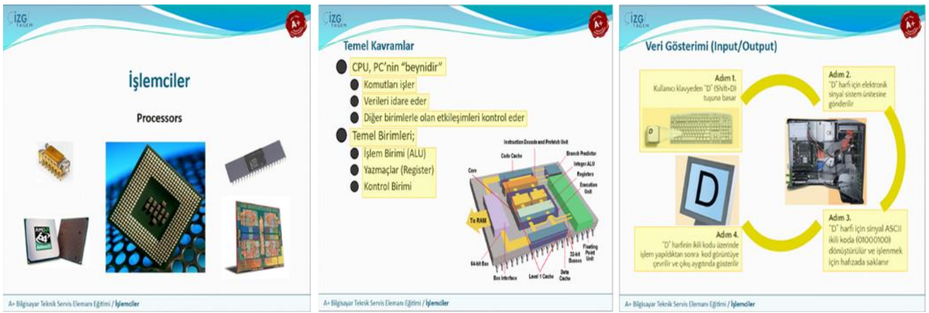

Figure 3. Course Material

Practical education (real-environment) visuals are presented in Figure 4. The course content was instructed to the students in the RE group with the course material. After 45 minutes of instruction (up to 1 hour), practical instruction was initiated.

Figure 4. Real Environment Experience

In the RE group, students were asked to disassemble and assemble computer parts with real objects (processor, ram, computer case, etc.). This stage took about 1 hour. The same instruction continued for 7 weeks.

AR Material and AR Experience Design

In the AR group, after the course was instructed with the ICT course material, the AR material was employed in the practical instruction. The AR material included a smartphone and an AR ICT book with QR codes. The AR material development included: storyboard development, barcode development, modeling, AR ICT notebook development, animation development, barcode and animation interaction, and the development of the mobile application. In the first stage, storyboards were developed based on the ICT course content. Then, barcode images were developed on Adobe Photoshop CS6 software. The barcodes included the pictures of the processor, RAM, video card, network card, sound card, motherboard, hard disk, power supply, and the computer case. Modeling and animation stages were designed on the Cinema 4D software. An AR ICT notebook was developed to allow the students to run the application and take notes. Two-dimensional images (QR codes) were defined as 'markers' with AR technology in the notebook. Thus, an infrastructure was developed for the students to interact with the notebook on their smart phones. The development of the animations with AR technology depends on the interaction between barcodes and animations. In the final stage, Armedia, a Cinema 4D add-on, was used for barcode - animation interaction, and the material included Android and IOS printouts. Before the experimental process, the students were informed in a seminar where they were allowed to try the AR material. Technical support was also provided during the seminar. The AR material was presented in Figure 5 and the experience images were presented in Figure 6.

Figure 5. AR Material

Figure 6. AR Experience

SM Material and SM Experience

In the SM group, after the class was instructed with ICT course material, the practice phase was conducted with the simulation material. A computer was required to use the simulation material. The material development process was generally similar to the AR material (except for book development). Part models were animated with Adobe Flash software and Action Script 3.0 code (Flash application was available on school computers), and simulation material was loaded on the computers. The student actively participated in some certain AR processes (e.g., the student could not proceed without disassembling the processor). Information was provided for the students in a seminar, and they were allowed to try the simulation material. The simulation material and experience images were presented to the students in Figure 7 and Figure 8.

Figure 7. SM Material

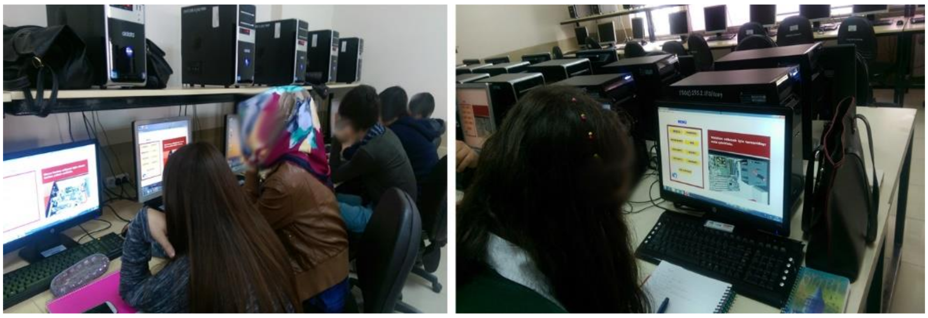

Figure 8. SM Experience

Data Collection Instruments

The data were collected with the Demographic Data Form, Learning Achievement Test, and the Psychomotor Skills Checklist

Demographic Data Form: A draft demographic data form was developed by the author to collect detailed participant data and determine the control and experimental groups. To ensure the content validity of the form, it was edited and finalized based on the views of two faculty members with a PhD on educational technologies.

Learning Achievement Test: The learning achievement test was developed by the authors. The test included 25 multiple choice questions. The test was scored out of 100 points, with four points awarded for each correct answer. The test questions were based on the ICT course achievements. A specification table was developed, and questions that reflected each achievement were determined. The final test was reviewed by three academic experts in computer education (Department of Computer Education and Instructional Technologies). The items were revised based on expert opinion. The reliability of the achievement test was calculated with the pilot scheme data (N=446). A Cronbach's Alpha coefficient of $\alpha < 0.50$ reflects low reliability, $0.50 \leq \alpha < 0.80$ reflects moderate (acceptable) reliability, and $\alpha > 0.80$ reflects high (good) reliability (Taber, 2018). Since the Cronbach's Alpha coefficient was 0.867 for the learning achievement test, it was accepted as reliable.

Psychomotor Skills Checklist: To analyze participant psychomotor performances, a psychomotor skills checklist was developed by the author to determine whether certain behaviors were performed in a certain order and submitted for expert opinion (2 assessment and evaluation specialists, 2 educational technology specialists with PhD degrees). The draft, the lowest possible score of which was 0 and the highest possible score of which was 146, was a 3-point Likert-type scale where performing the behavior at once was scored 2 points, performing the behavior on the second try was scored 1 point, and inability to perform the behavior was scored 0 points, and the checklist was finalized based on expert opinion. To ensure interrater agreement, students were evaluated by an educational technology specialist and researcher with a PhD during the application, and the results were analyzed with the Pearson correlation coefficient. Pearson analysis revealed that there was a statistically significant positive and high correlation (.93) between the author and expert scores. The checklist included 73 steps for each part (case, processor, ram, etc.), computer disassembly (i.e., "1. recognizes RAM. Unlocks RAM. Removes RAM from the socket"), and computer assembly.

Data Analysis

Quantitative study data were imported to the IBM SPSS 23.0 software. The normality of each variable was analyzed. A Two Way ANOVA was employed for composite measurements since there were three groups and two measurements (pretest and posttest) of learning achievement. A Wilcoxon signed-rank test was used to determine inter-group differences, since students' pre-test and post-test scores in psychomotor skills did not exhibit normal distribution ($p<.05$).

Findings

In the study, learning achievement levels and psychomotor skills of the students were determined. Descriptive findings for each group before and after the experiment are interpreted in Table 6.

Table 6.
Learning Achievement and Psychomotor Skills Score

Group	Test	N	Learning Achievement		Psychomotor Skills	
			Mean	SD	Mean	SD
AR	Pre-test	21	70.66	17.17	77.85	58.19
	Post-test		79.42	15.24	136.90	15.19
SM	Pre-test	21	70.09	15.47	61.52	61.60
	Post-test		73.71	13.59	134.85	11.09
RE	Pre-test	21	70.28	16.52	64.71	51.35
	Post-test		78.09	14.89	133.00	11.98

As seen in Table 6, The mean pre-test learning achievement scores of the AR, SM and RE groups (M_{AR}=70.66, SD_{AR}=17.17; M_{SM}=70.09, SD_{SM}=15.47; M_{RE}=70.28, SD_{RE}=16.52) were almost equal. Thus, the learning achievement scores of the groups were similar before the application. The mean post-test learning achievement scores of the AR, SM and RE groups (M_{AR}=79.42, SD_{AR}=15.24; M_{SM}=73.71, SD_{SM}=13.59; M_{RE}=78.09, SD_{RE}=14.89) demonstrated that the achievements increased in each group, and the highest increase was in AR group.

The mean pre-test psychomotor skills scores of the students demonstrated that the mean score was higher in the AR group (M_{AR}=77.85, SD_{AR}=58.19) when compared to RE (M_{RE} =64.71, SD_{RE}=51.35) and SM (M_{SM}=61.52, SD_{SM}=61.60) groups. The lowest mean pre-test psychomotor skills score was observed in the SM (M_{SM}=61.52, SD_{SM}=61.60) group. The mean post-test psychomotor skills scores of the students revealed that the mean score in AR group (M_{AR}=136.90, SD_{AR}=15.19) was higher when compared to the SM (M_{SM}=134.85, SD_{SM}=11.09) and RE (M_{RE} =133.00, SD_{RE}=11.98) groups. The lowest mean post-test psychomotor skills score was observed in the RE group (M_{RE} =133.00, SD_{RE}=11.98).

Can AR and SM Replace Real-Life Experiences in Learning Achievement?

Two-way Mixed Design ANOVA was employed to determine the significance of the effect of the increase in the mean learning achievements of the groups on post-test scores. The findings are presented in Table 7.

Table 7.
Learning Achievement of the Groups

Source of the variance	Sum of Squares	Sd	Mean square	F	Significant (p)
Between subjects effects	21245.71	62			
Group (Experimantal/Control)	233.90	2	116.95	.33	.71
Error	21011.81	60	350.19		
Within subjects effects	9991.99	63			
Measurement(pretest/posttest)	1347.17	1	1347.17	9.52	.00
Group* measurement	161.77	2	80.88	.57	.56
Error	8483.04	60	141.38		
Total	31237.70	125			

As seen in Table 7, there was a significant difference between the learning achievements of the students in each group based on time (between pre-test and post-test) ($F=9.52$, $p>.05$). This finding demonstrated that the experimental procedure led to a significant difference in the learning achievement scores of the students. However, there were no significant differences between the experimental groups and pre-test and post-test learning achievements ($F_{(2,60)}$=.572, $p>.05$). Thus, it could be suggested that the learning achievement scores of the students in the AR and SM groups increased between the tests when compared to RE; however, the difference was not significant.

Can AR and SM Replace Real-Life Experiences in the Development of Psychomotor Skills?

In the study, the Wilcoxon signed-rank test was employed to determine whether the psychomotor skills of the students significantly differed before and after the application, and analysis results are presented in Table 8.

Table 8.
Pre-Test and Post-Test Psychomotor Skills Scores of the Students

Group	Pre-Test – Post-Test	N	Mean Rank	Sum of Ranks	z	p	r
AR	Negative	0	.00	.00	-4.01	.00	-0.57
	Positive	21	11.00	231.00			
	Tie	0					
SM	Negative	1	5.50	5.50	-3.82	.00	-0.63
	Positive	20	11.28	225.50			
	Tie	0					
RE	Negative	0	0.00	0.00	-3.92	.00	-0.67
	Positive	20	10.50	210.00			
	Tie	1					

As seen in Table 8, the difference between the pre-test and post-test scores of the students in the experimental and control groups was statistically significant ($z_{AR} = -4.01$; $p < .05$, $z_{SM} = -3.82$; $p < .05$, $z_{RE} = -3.92$; $p < .05$). Based on the mean rank and total ranks of the score differences, the difference favored the positive ranks; thus, the post-test scores. Effect size analysis revealed that the psychomotor skills of the students in the AR (r=-0.57), SM (-0.63) and RE (r=-0.67) groups improved moderately. According to Cohen (1992), an effect size of 0.2 could be considered as a weak effect, 0.5 as a moderate effect, and 0.8 as a high effect.

Discussion, Conclusion, and Suggestions

Alternative solutions that are effective and equivalent to real-life experiences are required to improve the learning achievements and psychomotor skills of the students. Thus, the possibility to replace real-life experiences with augmented reality and simulation applications to improve the learning achievements and psychomotor skills of university students in the ICT course was investigated in the present study.

The analysis of the three environments based on learning achievement demonstrated an increase in the post-test scores when compared to the pre-test scores in all groups. However, there was no significant difference between the experimental groups and pre-test and post-test learning achievement scores. This finding demonstrated that all three environments increased learning achievement. Thus, augmented reality, simulation, and real-life experiences in the ICT course learning environment similarly affected the learning achievements of the students. The insignificance of the difference could be due to the course. Garzon et al. (2017) and Li et al. (2021) reported that the field where AR was implemented had a significant effect on student academic achievements. Previous study findings revealed that AR had a moderate effect on academic achievement in earth and space sciences, physics, and mathematics, while the effect was low in biology. It also had a minor impact on broad fields such as information and communication technologies and education (Garzón & Acevedo, 2019). It has been reported that AR affected academic achievement more in disciplines where abstract concepts are instructed. Since actual objects were employed in our study, the low effect size was acceptable. The analysis of the differences between the pre- and post-test learning achievement scores in all groups revealed that the learning achievements of the students in the AR group were higher when compared to the SM and RE groups, the learning achievements of students in the RE group were higher when compared to the SM group. In contrast to our study findings in the literature, students' learning achievements in AR-assisted learning environments in different disciplines were better when compared to conventional instruction (Gül & Şahin, 2017; Ibáñez et al., 2020; Şahin & Yılmaz, 2020; Yip et al., 2019), and it has been reported that the effect was moderate (Batdı and Talan, 2019; Chang et al., 2022; Garzón and Acevedo, 2019; Küçük-Avcı et al., 2019; Özdemir et al., 2018). Similarly, it was reported that AR was more effective on learning achievement when compared to SM (Aldalalah et al., 2019). The positive effect of AR on learning achievement could be due to the employment of new technologies (first time exposure to AR). The inclusion of the students in different learning environments could help them acquire knowledge more effectively. Integration of new technologies into educational environments increased active participation in the class and student interest and facilitated learning (Bacca Acosta et all., 2014; Godwin-Jones, 2016; Hsiao et al., 2016; Ibáñez et al., 20120 Vermeulen & Buuren, 2013). The effect could also be due to the realistic, effective, efficient and interesting learning environment provided by AR systems. Simulated learning environments allow students to practice at their own pace and based on their skills, leading to a more flexible learning environment when compared to physical learning environments (Krueger, 1993; Zacharia & Olympiou, 2011). AR system features such as simultaneous virtual and real objects, high interaction and hands-on experiences also play a key role in academic achievements (Hsiao et al., 2016; Lai & Chang, 2021).

In the analysis of the three environments based on psychomotor skills, a statistically significant difference was determined between the pre-test and post-test psychomotor skill scores of the groups. The effect was moderate in the AR, SM and RE group. Thus, effects of the augmented reality, simulation or real-life experiences in ICT course learning environment were similar on the psychomotor skills of the students. The acquisition of psychomotor skills is critical in certain areas. Garzón and Acevedo (2019) reported that it could have higher effects in engineering, manufacturing and construction education when compared to other fields. It was reported that AR was more effective in learning complex and difficult psychomotor skills such as physical education (Chang et al., 2020), music (Orman et al., 2017), maintenance and repair (Chiang et al., 2022; Eswaran et al., 2023; Wagner et al., 2023). Thus, the field and topic selected in the research are important. Studies demonstrated that AR was effective in procedural tasks that improve psychomotor skills (Mourtzis et al., 2020, Webel et al., 2013; van Lopik et al., 2020). This could be due to the association of AR with real objects and 3D images. The biggest advantage of AR was that it allowed interaction with real-world objects and simultaneous access to virtual information for reference. Realistic conditions could easily be created with AR using audio, video, links and text in a 3D object. In this realistic environment, students could repeat certain tasks several times. It allows the development of movement patterns and psychomotor skills as the students repeat certain tasks. The psychomotor skills begin to develop when the task is performed for the first time (Webel et al., 2013). Thus, students could acquire direct experiences similar to those in the real world (Khan et al., 2023). AR could reduce psychomotor errors (Blattgerste et al., 2012; Uva et al., 2018; Vanneste et al., 2020) and student stress during novel tasks (Vanneste et al., 2020). Thus, it could reduce mistakes since the learners feel safer. AR allows inactive students in learning due to individual differences to participate more. It contributes to the development of psychomotor skills by allowing students to learn by doing and experiencing. AR technology is immersive, ensuring the participation of students and facilitating learning by doing (Chiang et al., 2022), leading to an almost real-life experience. Similarly, the psychomotor skill scores of the students who practiced with SM were higher when compared to the RE group. Simulation has several benefits for students who learn psychomotor skills. It allows students to synthesize relevant components before working in a real environment. Like AR, SM also reduces student anxiety during practice and improves their confidence, satisfaction and self-efficacy in learning (Karataş & Tüzer, 2020; Lei et al., 2022; Üzen-Cura et al., 2020). Since real environments are imitated in SM, students are expected to apply learned knowledge in simulations easily when compared to real environments (Wilford & Doyle, 2006). The overall findings suggested that AR and SM could improve university students' psychomotor skills in the ICT course, similar to the real-life setting.

In conclusion, the benefit of real-life experiences for learning outcomes has been documented in several studies. However, when factors such as student profiles, crowded classrooms, technological advances, natural disasters, etc. are considered, the conventional method can not meet the requirements and the students can not practice. Thus, solutions that would meet student requirements, allow practice, and be equivalent to real-life experiences are needed. The present study was designed due to meet this requirement. The study findings demonstrated that learning environments assisted by augmented reality and simulation applications were at least as effective as learning environments that offer real-life experiences in terms of learning achievements and psychomotor skills. Chang et al. (2022) reported that augmented reality-assisted learning environments were better than other environments in learning achievements and psychomotor skills. Because the realistic conditions provided by AR allow the students to acquire experiences similar to the real world. Thus, the present study concluded that augmented reality or simulation applications could be employed in learning environments where real-life experiences were not available.

The present study findings should be interpreted based on certain limitations and revised based on the recommendations. Initially, the study was designed as a media comparison, and is limited to concurrent simulation, augmented reality, and real object use as mentioned in Milgram and Kishino's (1994) reality-virtual reality continuum. Future studies could compare other technologies used in AR and other environments (Augmented Virtuality, Virtual Environment). Also, value-added studies should be conducted instead of media studies. In these studies, a variable is investigated by comparing different variations of the same technology (Buncher et al., 2021). Different learning environments could affect learning outcomes differently. Thus, learning outcomes should be investigated with different learning strategies in AR or SM environments. For example, a study could be planned based on learning environments and learner traits. Second, learning achievements and psychomotor skills were limited to learning outcomes in the present study. Several studies have evidenced that AR supports learning. However, since the number of studies on psychomotor skills is limited, future value-added studies could be conducted on this variable. Thus, the effects of mobile AR and traditional AR on psychomotor skills could be investigated. Also, the effect of the learning environment on knowledge retention should be investigated. The third limitation of the study was the limited sample size (63 students). One of the parameters that directly affects the significance of the findings is the sample size. The sample size could affect statistical strength and influence the results. A large sample increases the probability of meaningful findings (Keskin, 2020). Thus, it was recommended to repeat the study with a larger sample size. Fidalgo et al. (2023) reported that augmented reality was more effective on skill acquisition as well as academic achievement in virtual classrooms when compared to virtual classrooms that were not assisted by augmented reality in online education. Thus, augmented reality could have an important potential in distance education. The same learning outcomes could be investigated with different AR tools in online learning environments in future studies. The present study would assist future applications, instruction, and research. It would be beneficial for the students, who desire to improve themselves and their professional skills by practicing ICT course, teachers who desire to include current technologies in their instruction and employ alternative material in learning environment, and researchers who desire to conduct research on educational technologies, interested in the educational aspects of computers (computing), and educational technologists.

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Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

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