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Development and Evaluation of an Image Processing-Based Kinesthetic Learning System

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Abstract: This study aims to develop an interactive language learning game and explore its efficacy for English language learners. A computer-generated playground was projected onto a large classroom floor (4×3 m) with a wide-angle projection device. A Kinect depth camera determined the spatial positions of the playground and the positions of the students' heads, feet, and bodies. Then, we evaluated the system's effect on English education through pre- and post-tests. While there was no significant difference between the groups in terms of achievement in the pre-tests, the experimental group exhibited significantly greater improvement in the post-tests (F: 14.815, $p < 0.001$, η^2p: 0.086). Also, both groups demonstrated significant learning gains in post-tests compared to pre-tests (F: 98.214, $p < 0.001$, η^2p: 0.383), and the group x time interaction of the experimental group increased more in percentage (32.32% vs. 17.54%) compared to the control group (F: 9.166, $p < 0.003$, η^2p: 0.055). Qualitative data from student views indicated enhanced learning pace, vocabulary acquisition, enjoyment of the learning process, and increased focus. These findings suggest that a kinesthetic learning environment can significantly benefit English language learning in children.

Keywords: visual processing; kinesthetic; movement; learning; projection device

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1. Introduction

Recently, many researchers in psychology and education have focused on individual differences in learning processes and suggested activities that take these differences into account [1–4]. The theory of multiple intelligences can help explain individual differences in abilities and skills [5], especially in language learning contexts where learners come together from different linguistic and cultural backgrounds [5]. Individuals may perceive their environment visually, auditorily, or kinesthetically (bodily), and their learning styles may change according to how they perceive their environment [6]. Fleming and Mills [6] proposed four learning styles, including the kinesthetic style, and the following studies [6] showed how kinesthetic learning improves students' learning outcomes.

Traditional instruction across a range of subjects, including foreign language teaching, typically relies on static visual materials and occasionally employs audiovisual content.

This learning paradigm commonly assigns students to remain seated for extended periods within classroom environments. However, research shows that prolonged sitting (20–30 min) leads to a significant redistribution of blood flow, with roughly 80% accumulating in the lower body [7]. This seating design reduces the brain's oxygen amount, induces drowsiness, and decreases focus [1]. In order to eliminate this disadvantage, many studies recommend incorporating physical activity into the learning environment [8,9]. In parallel with technological advances, recent studies on neurophysiology have supported the idea that movement can be an effective cognitive teaching model by improving memory and increasing student motivation and interest in the lesson [10,11]. Similarly, Davis argued that stimulation of the vestibular (inner ear) and cerebellar (motor activity) systems by movement activities can lead to significant gains in attention and reading [12].

The region of the brain primarily linked to motor control is the cerebellum. Interestingly, the segment responsible for processing movement is also the one involved in learning [12]. Contrary to expectations, visual data indicate the generation of new brain cells during physical activity. Pre-physical activity examination of the hippocampal region shows heightened blood flow following such activity. Activities involving play contribute to increased blood volume, providing evidence of the formation of new cells in this area. Magnetic resonance imaging (MRI) scans visually demonstrate the tangible growth of new neuronal connections following physical activity [12]. One of the effects of movement on the brain is amines (weak derivatives of ammonia). Amines are one of the brain's primary fuels in the attention system [13]. Physical movement increases the amine ratio [14]. The research on amines has revealed that a simple walk supports an increase in amines, leading to increased attention levels [13].

Moreover, Jensen [14] reported that physical movements trigger the release of stress hormones such as epinephrine and norepinephrine (adrenaline), increasing students' arousal levels and making them ready to learn. Another new theory [6] proposed that the brain is like a muscle, growing when used and weakening with inactivity. Similar to cognitive activities, physical and playful activities contribute to brain growth. Although physical movement does not make people more intelligent, it helps people focus better and optimizes the brain for learning [6]. These studies, conducted for different purposes and populations, show a potential relationship between physical activity and learning. The students who learn academic content with movement are better motivated by discriminating important information from unnecessary information, depending on the nature of the activity [6]. In psychology, this state of "arousal" can be achieved by incorporating physical activities into classroom activities, because movement increases sensory awareness, motivation, and attention, leading to effective learning [15]. Kinesthetic learning intends to strengthen students physically, emotionally, and academically. Through an active learning environment, students are more willing to cooperate because of the fun instruction, leading to less misbehavior [16]. Moreover, educators have begun incorporating kinesthetic learning activities in their classrooms because of the increased pressure for high test scores and reductions in physical education programs [17].

In the literature, movements used for educational purposes at school are divided into learning-based and non-learning-based movements. Learning-based movements aim to trigger learning and improve its quality through movement [18–23]. These movements are primarily used in mathematics, foreign language, and science courses. For example, Caterino and Polak [24] divided the students in a class into control and experimental groups. The experimental group did stretching and physical movements in the first 15 min of the lesson and then participated in the lesson again. Achievement tests were applied to both groups before and after the applications. At the end of the study, the experimental group achieved significantly more than the control group. The researchers also stated that students participating in physical activity can dramatically increase their mental concentration [24]. In a study by Hillman et al. [25], the control group was tested after 20 min of sitting, while the experimental group was tested after 20 min of running on a treadmill. The achievement test scores and the attention measurement results of the participants showed that physical activity increased attention and academic achievement more positively. The results of an American Academy of Pediatrics study of first and second graders suggest that exercise and voluntary movement may be associated with higher academic test scores. In a pre-arranged movement-based learning laboratory, students participated in activities such as saying the names of colors on colored steps while climbing stairs and moving on scooters over shapes on the floor to draw and name the shapes. The study reported that students' academic achievement tests increased significantly [8]. Studies on hyperactive students show that using therapy balls in lessons increases students' focus and thus contributes to academic achievement [26,27]. In their study, Vazou et al. [11] showed that physical movement practices in the classroom environment motivated students by entertaining them much more, increasing their academic achievement. In a study conducted by Flippin [16], the impact of employing kinesthetic equipment on students' task behaviors was explored. Using exercise balls and standing desks in the classroom revealed a noticeable increase in task behaviors. These findings suggest that incorporating more movement into the classroom environment can prove advantageous for teachers, without requiring extensive planning and instruction time.

Another investigation by Beserra [28] delved into the acceptability and feasibility of delivering physically active academic lessons through dance. Thirty-seven teachers developed a series of dance routines based on mathematical functions. They asserted that synchronizing the mind and body enhances motor, coordination, memory, reading, speech, language, and mathematical skills. Additionally, the study noted a growing interest among teachers in integrating physically active academic lessons into their regular school routine.

Interactive motion-based games have recently attracted more attention as an alternative to computer-based educational games. One of the most popular applications in this field is the XBOX game system developed by Microsoft. The essential feature of the Kinect camera set for interaction in this system is its ability to detect the movements of the human body and transfer them to a computer environment in a non-contact way. In this system, a person enters the game in three dimensions and interactively participates. This system is used not only for gaming purposes but also for education and training activities. Zhang [29] reported that Kinect allows students to communicate more with games through their movements. As a learning tool, XBOX Kinect potentially increases student motivation and creates a pleasant classroom environment [29]. Numerous studies [30,31] have documented the potential benefits of Kinect-based interactive systems for language learning, demonstrating efficacy when compared to traditional methods. Through this technology, a person can create movement in the system by using only their bodily limbs from the point where they are located. This leads to movement limitation and does not reflect real movements. Similarly, while touchscreen smart boards offer multisensory interaction to teachers and students, their limited screen size and static positioning present constraints on movement diversity and range, potentially hindering kinesthetic learning. Therefore, it is important to create computer game-based programs embedded within classroom settings. Such programs can leverage the inherently engaging nature of games while promoting active participation and natural, embodied language use, potentially offering a more holistic and effective approach to foreign language education. Recently, the development of projection technology has helped us obtain wide-angle images with a high resolution from short distances. Also, the fact that depth cameras can determine people's limbs and spatial positions motivates the idea that a large area can be used as a touch screen. Based on this idea, we developed a kinesthetic learning system in which we created a training and game area on the floor (4 × 3 m) with a high-resolution projection device mounted on the ceiling of a classroom to perceive the limb movements and spatial positions (x, y, and z) of students in a game area with the depth camera, thus creating a large touch area and allowing us to develop game software containing the words and dialogues of the "Fun With Science", "Prepositions", and "Jobs" units. With this system, students can interact with the learning content through movement within the designated area. Based on our review of the literature, this study is the first in its field and will make valuable contributions to the literature. Therefore, this study aims to investigate the effect of the developed system on English language learning achievement and tries to answer the following research questions:

- How does teaching English with the newly developed system affect students' word learning levels compared to the classical method?
- What are the students' attitudes and opinions toward this system?

2. Materials and Methods

2.1. Experimental Design

This study was carried out in two phases. The first phase was the development of the system, and the second phase was the evaluation process of the developed system. The learning environment designed in this planning process was created based on [32] "Generic Model" instructional design model. When the stages of this model, called Analysis, Design, Development, Implementation, and Evaluation (ADDIE) were examined, this model completely fit with the purpose of this study. In the analysis step, the learning environment (technological equipment in the school, existing equipment, and classroom layout) was analyzed, and pre-tests were administered to determine students' prior knowledge of the vocabulary in the relevant units of the curriculum. In the design stage, we designed the learning environment, selected the appropriate visuals and data to be used in the system, coded software, reviewed the measurement tools, and finalized them. In the development step, the final data entries for the system were provided, and a piloting application was tried with a few students. This step helped to bring the system to its last version. In the implementation phase, the image processing-based kinesthetic learning system was put into use, the active participation of the learners was ensured, and appropriate prompts and reinforcements were given through the system. In this process, data on the effectiveness of the process were collected through student opinions and video recordings. Finally, in the evaluation step, post-tests were applied to determine the system's effectiveness in the experimental group and the lesson taught in the control group. Following implementation, we collected students' opinions about their motivation, focus, and attitude toward the course.

2.2. First Phase

Development of the Image Processing-Based Kinesthetic Learning System

The first phase was to develop the hardware and software contents of the image processing-based interactive kinesthetic learning system.

Physical Layout of the Projection Device

A projection device Xbox 360 (HD29He; Optoma, Fremont, CA, USA) with 4000 lumens was used in this study. The physical layout in Figure 1 was transferred to the school environment. The lens of the projection device mounted at a height of 3.8 m from the entrance wall of the activity area, centered on the activity area, was oriented so that the part where the lens of the projection device was located would see the floor, and a reflection area of approximately 15 m^2 was created on the floor. While determining the projection area, the field of view that the Kinect sensor could detect during movement was taken into account. The projection device settings in Table 1 were used for image enhancement of the projected image. In order to transfer the data received from the Kinect device to the projection device accurately and to minimize the deviations in the vectorial positions of the limbs, the lens of the projection device hanging on the wall and the camera in Kinect One were aligned. In this way, the positions of the body parts in the game were transferred accurately. The distance from the Kinect sensor to the projection mirror was never below the sensor's field of view. For this sensor, which can detect objects at a minimum distance of 1 m, the distance between the projection and the Kinect sensor was set to 1.4 m.

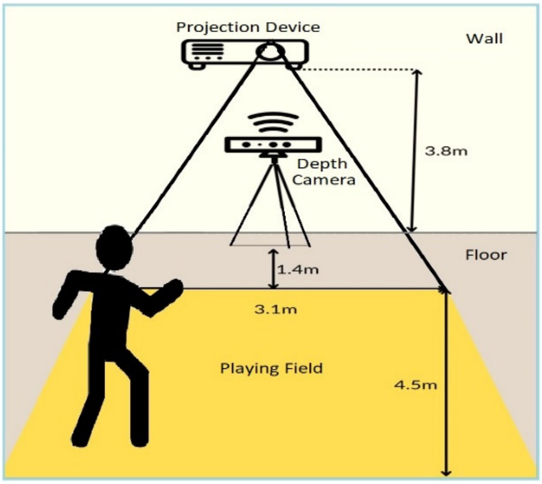


Figure 1. Physical layout of the system (Yellow; Playing Field, Brown; Floor, White; Wall).

Table 1. Technical details of the projection device.

Menu	Sub-Menu	Rate	Preference
Screen	Aspect ratio	4:3 16:9 LBX Natural Auto	16:9
	Edge masks	0~10	1
	Keystone correction	−40~40	−17
Audio	Silent	Open Closed	Open
	Audio	0~10	10
Settings	Projection	Front Rear Ceiling Rear top	Rear top

Optimization of the Data in the System

In the design of the projection-based kinesthetic English language learning module, the data received from the Xbox Kinect One sensor were converted into coordinate data through the Kinect for the Windows SDK v1.8 program. This plugin made the data meaningful, and the limb positions on the x, y, and z axes were accurately transferred to the computer environment. The x data from the Kinect sensor define the position of the selected limb on the horizontal axis, the data on the y-axis depict the position of the selected limb on the vertical axis, and the data on the z-axis define the distance between the selected limb and the sensor. The communication between the program plugin and the data received in the Unity game engine used in the realization of the games was provided by the Kinect for the Windows Unity Pro 2.0 library.

Figure 2 shows the skeletal system structure that can be obtained from the Kinect sensor. In this study, after creating the test setup, we predicted that the data from joints 0, 3, 15, and 19 in Figure 2 could carry the appropriate characteristics for the system requirements. However, after the experiments, the data from limbs 0 and 3 caused incorrect responses. These limbs may have remained in front or behind when the person bended or jumped. As a result, the best coordinates were obtained from the right and left foot joints numbered 15 and 19, respectively. In this way, the margin of error between the data received from the sensor and the position of the person in the game was reduced to $\pm$8 cm.

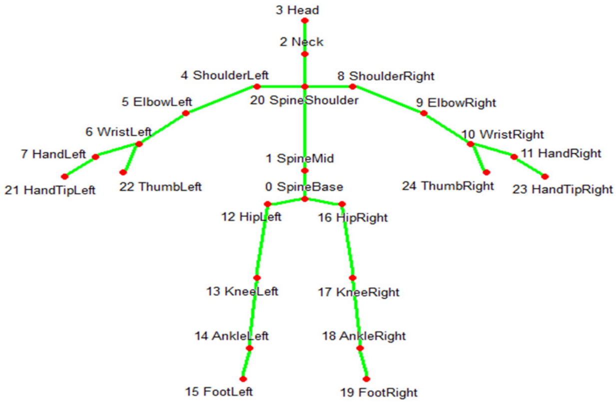


Figure 2. Positions of the limbs in the skeletal system from the Kinect One sensor.

Projection-Based Kinesthetic Learning System

The software interface (Figure 3) was designed to be quite simple and plain in order to be user-friendly. When the software is started, the entire curriculum and the activity content of the curriculum are listed. As explained in Table 2, the program includes a total of 13 different activities belonging to 3 different topics. High-frequency and low-decibel background music (jazz and/or classical) was added to the games to contribute to people's attention and focus. Figures 4–6 depict the interface of the activity-based games belonging to professions, prepositions, and science sections. Table 2 shows the vocabulary and sentence groups determined as the outcomes of these sections.

Figure 3. Main menu designed for the application.

Unity engine 2021.3.21f1 LTS version was used to create the activities in the design of the projection-based kinesthetic English language learning module. Game scenarios were created in line with predetermined game scenarios and activity objectives. The elements that provide the game dynamics in the programming of the games are the right and left foot coordinate data received from the Kinect sensor and subjected to a certain pre-processing. The developed activities can be used in 64-bit and 32-bit Windows operating systems.

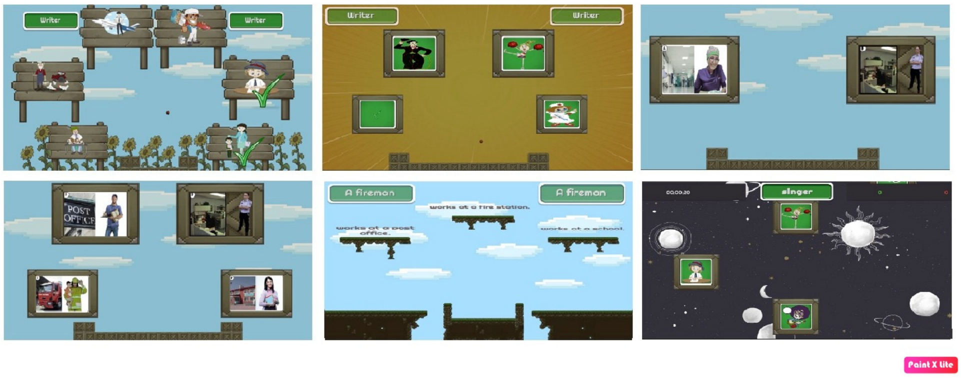


Figure 4. Professions section game designs.

Table 2. Topics, target vocabulary items, and target sentence groups used in the English lesson.

Topic	Target Vocabulary Items	Target Sentence Group
Professions	Doctor, Farmer, Writer, Painter, Teacher, Businessman, Singer, Actor, Actress, Pilot, Policeman, Nurse, Fireman, Vet, Waiter, Chef	A nurse works at a hospital.
		A chef works at a restaurant.
		A teacher works at a school.
		A fireman works at a fire station.
		A policeman works at a police station.
		A postman works at a post office.
Prepositions	In, On, Behind, Under, In front of, Near	It is under the television.
		It is in front of the sofa.
		It is between the three chicks.
		It is behind the sofa.
		They are on the bookshelf.
		It is on the sofa.
		It is near the sofa.
		It is on the wall.
Science	Break, Cup, Experiment, Flower, Fold, Freeze, Glass, Goggles, Jar, Melt, Mix, Paper, Pebbles, Peel, Plant, Pour water, Put, Science, Toothbrush, Scissors	Fold the paper.
		Melt the ice.
		Do an experiment.
		Plant a flower.
		Pour some water.
		Break an egg.
		Peel an orange.
		Freeze the water.

Figure 7 shows the physical environment where the system was implemented in the pilot school. The system allows one user to six users to perform the activities simultaneously. Thus, the level of entertainment was increased by creating competition among students. Also, there are different levels in the games, and the activity levels can be adjusted according to the level of the student, from easy to difficult. Similarly, the duration and difficulty level of the games can be adjusted by the teacher according to the level of the students.

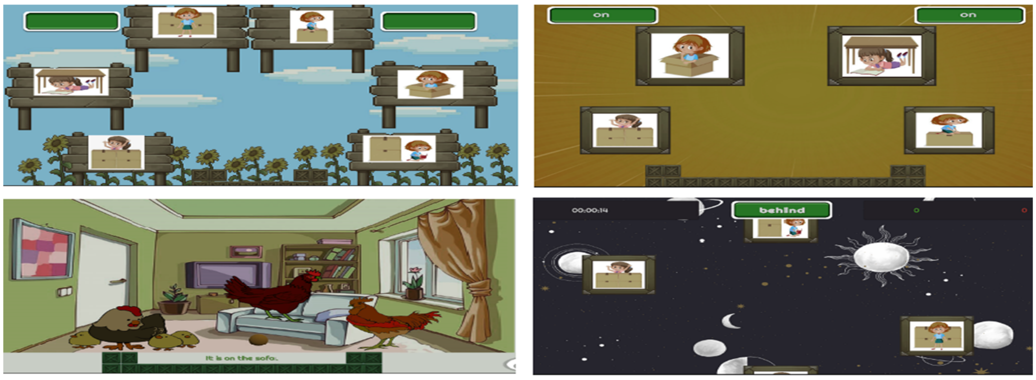


Figure 5. Prepositions section game designs.

Figure 6. Science section game designs.

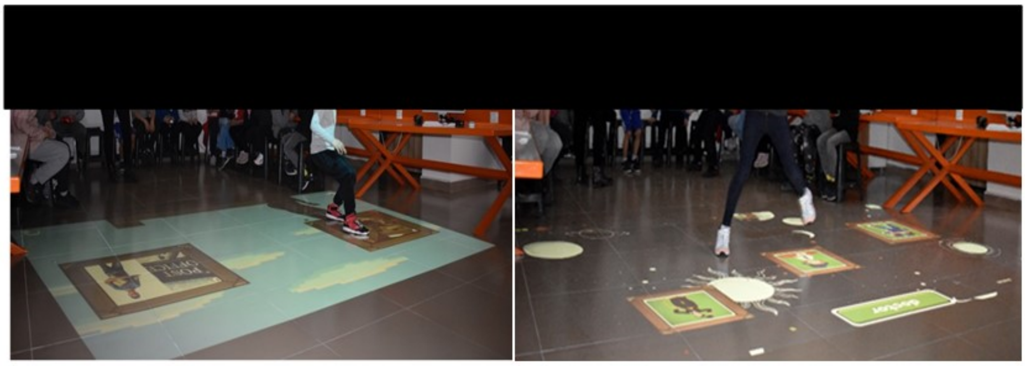


Figure 7. Application in the classroom.

How the System Works

Since the position of the image is clear when any image to be shown in the software is reflected on the floor, the system is designed to perform a new operation when the position of the student's feet is in the same position as the image. Figure 7 shows that the spelling of an English word was projected on the floor, and an audio stimulus was given through the projection software. Then, the correct image of the given word and the wrong images were projected at various points of the projection area. As soon as the student moved to the correct image and put his/her foot on it, the depth camera detected the spatial position of his/her feet, and a new operation was performed. If the student selected the wrong image, a red cross appeared next to the warning buzzer. The visuals were animated (the visuals moved around in the playground) in some of the applications in the system software, and the students were asked to react according to these animated visuals. For example, when the spelling of an English word and the audio stimulus were given, one correct image and

3–4 incorrect images started to flow in the upper part of the projection projected on the floor in the game-based exercises. The student was asked to select the correct image by moving quickly without leaving the projection area or stepping on the wrong images. The applications such as games, exercises, tests, group work, and so on were developed based on fixed and moving images.

2.3. Second Phase

Evaluation of the System

In implementing and evaluating the system, we designed the research process following an explanatory sequential design, which started with a quantitative stage and continued with a qualitative stage to explain the quantitative results. Qualitative data were analyzed to help explain the quantitative results [9]. In the quantitative stage of the study, we calculated statistical significance, confidence intervals, and effect sizes and presented the main findings. The research was finalized by continuing with the qualitative stage to explain the quantitative results. In this process, a semi-structured interview method was applied to obtain the students' opinions about the system's effectiveness. Thus, this two-stage evaluation process built on itself helped us understand the effect of the image processing-based kinesthetic learning system more reliably.

The first stage of the evaluation was conducted on the experimental and control groups formed in accordance with the quasi-experimental design, one of the quantitative research designs. The effects of the developed image processing-based kinesthetic learning system on students' foreign language learning levels were determined with the experimental group's applications. The experimental and control groups, whose application conditions were equalized, were administered the pre-test developed by the researchers regarding the "Fun With Science", "Prepositions", and "Jobs" units before the procedure. Then, the experimental group students were taught language through the image processing system, while the control group was taught in accordance with the curriculum. After three weeks of implementation, a post-test was administered to both groups, and student scores were compared in terms of significant differences. After analyzing the quantitative data in the first stage of the evaluation, the second stage, the qualitative stage, was started. In the qualitative stage, the data on the implementation, usability, and perception of the image processing-based kinesthetic learning system were collected and evaluated through focus group interviews with the experimental group students.

2.4. Participants

The study group of the research consisted of 81 students in two different classes studying in the fourth grade of primary school (experimental group n: 41 and control group n: 40). The socioeconomic level of the students was mainly at the middle level and consisted of parents who were closely interested in student achievement.

Since the experimental group was underage, a "Family Consent Form" was prepared for them to be allowed to participate in the study. In addition, the ethics committee approval report numbered 86,082 was obtained from the Afyon Kocatepe University's ethics committee at the Graduate School of Social Sciences.

2.5. Application Procedure

This study was conducted for five weeks with the participation of fourth-grade primary school students. A total of three applications were conducted for three weeks after the pre-test, lasting one class hour (40 min) per week. Within the scope of the fourth-grade English curriculum, a total of eighteen unknown words in two units in the textbooks were identified. The words were taught with the developed system in the experimental group during one class hour of the three-hour weekly English lesson for three weeks and then reinforced with different activities. The selected words were taught and reinforced in the control group with the traditional method (slide show). Before the study, both groups' prior knowledge (pre-test) about the words to be used was determined. The same test was administered to the groups again as a post-test after the activities were completed. While planning the activities, we endeavored to design different activities for the control and experimental groups to teach the same vocabulary for the same periods of time.

2.6. Quantitative and Qualitative Research

This study used a semi-structured interview form, video recordings, and the researchers' diary as qualitative data collection tools. The Vocabulary Knowledge Scale was used as a quantitative data collection tool. This scale was developed by Paribakht and Wesche (1993) [33].

2.7. Data Analysis

We used descriptive analysis in this study. It is an analysis technique in which the conceptual structure of the research is clearly determined in advance. The primary purpose of descriptive analysis is to quantify qualitative data, analyze descriptive possibilities with frequencies, and transfer the findings to the reader in an organized and interpreted manner. Finally, the findings were enriched and interpreted with relevant texts according to their importance in answering the research questions, and the findings were supported with direct quotations. In order to increase the reliability of the determined themes and codes, more than one researcher independently marked the interview forms and the interview coding key by marking the appropriate option for the interviewed students' opinions on the relevant interview coding key. To determine the consistency of the markings by the researchers on the interview coding key, we checked the answers to each question one by one. We marked them as "Consensus" or "Disagreement", and the calculation was made using Miles and Huberman's reliability formula P (Percentage of Consensus) = Na (Consensus)/Na (Consensus) + Nd (Disagreement) $\times$ 100 to ensure validity and reliability(reference).

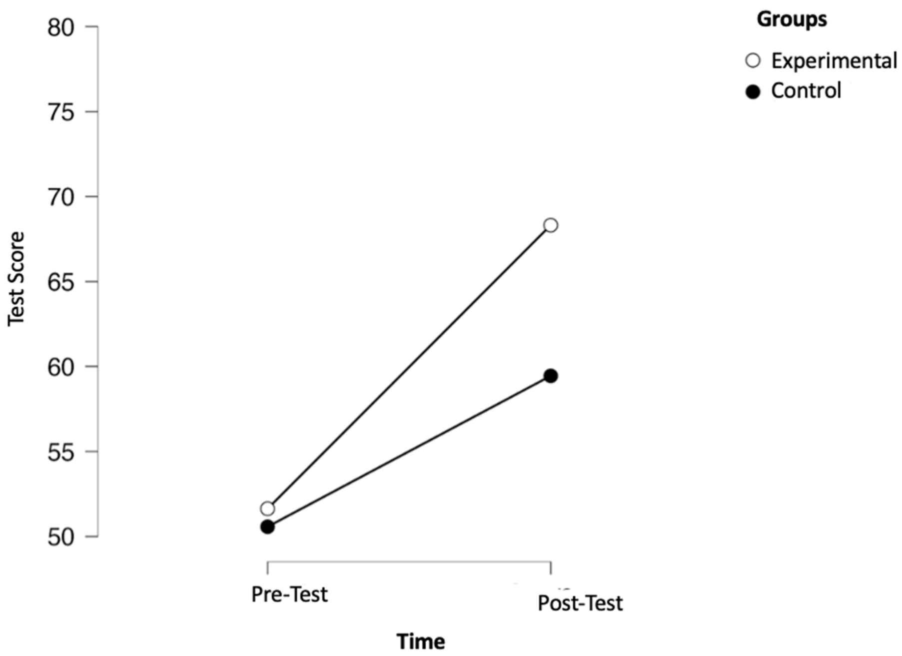
The SPSS 18.0 (Statistical Package for the Social Sciences) package program was used in the statistical analysis of the quantitative data. Descriptive statistics such as the percentage, frequency, and arithmetic mean were used to analyze the quantitative data collected at different stages of the study. The repeated measures ANOVA test was applied to determine the differences according to group and time interaction. A value of $p < 0.05$ was taken as a significance value. A partial η^2 was used to determine the effect size. For the partial η^2 values, 0.01 was considered a low effect size, 0.06, a medium effect size, and 0.14, a large effect size. Pre-test and post-test proportional (%) differences in the groups were calculated by the following formula: ((post-test − pre-test)/pre-test × 100).

3. Results

Figure 8 shows a significant difference between the repeated measurements of the experimental and control groups in terms of Group: F: 14.815, $p < 0.001$, η^2p: 0.086; Time: F: 98.214, $p < 0.001$, η^2p: 0.383; GroupxTime: F: 9.166, $p < 0.003$, η^2p: 0.055. Although the Bonferroni (post hoc) test showed no significant difference between the experimental and control groups in the pre-tests (<0.10), a significant difference was found in favor of the experimental group in the post-tests (68.317 $\pm$ 8.033 vs. 59.450 > 8.670). Furthermore, there was a significant increase in the post-tests compared to the pre-tests ($p < 0.001$) in both groups ((experimental group pre-test: 51.634 $\pm$ 6.647 vs. post-test: 68.317 $\pm$ 8.033), (control group pre-test: 50.575 $\pm$ 9.279 vs. post-test: 59.450 $\pm$ 8.670)); however, the groupxtime interaction results revealed that the experimental group showed a higher increase in percentage (32.32% vs. 17.54%) compared to the control group.

How Did Students React to the Image Processing-Based Kinesthetic Learning System?

In this section, we analyzed the answers the students gave to the questions in the questionnaire form and present them in line with the study's aims. The forms collected from the students were coded as S1, S2, S3,. . .S38, and the statements revealing the views of the students were quoted in accordance with these codes. At this stage, similar and different parts of the data were noted, and the coding process was carried out. The questions in the interview form formed the categories of the research. The categories identified are the following: "the contribution of learning English through the kinesthetic learning system to students", "students' views on English vocabulary learning activities through the kinesthetic learning system", "the use of this application in other courses", and "students' views on the differences in kinesthetic learning system application from other educational tools". The data under these categories were analyzed descriptively.



Group: F:14.815; $p < 0.001$; η^2_p: 0.086
Time: F:98.214; $p < 0.001$; η^2_p: 0.383
Group x Time: F:9.166; $p < 0.003$; η^2_p: 0.055
Change percentage: Experimental group: 32.32%; Control group: 17.54%

Figure 8. Change values of experimental and control groups according to group time.

The students were asked what they gained from learning English through the kinesthetic learning system, and their views on this issue were determined. Table 3 shows students' views on learning English through the kinesthetic learning system.

Table 3. Contributions of the kinesthetic learning system to students' English learning.

Category	F	%
Faster learning	14	28
Contributed to my learning	12	24
Learning vocabulary items permanently	10	20
Fun	6	12
Did not contribute to my learning	4	8
Learning by moving	4	8
Total	50	100

Table 4 shows that the students learned faster (28%), learned unknown words permanently (20%), found it fun (12%), and learned by moving (8%). While some students reported the system's contribution to their learning (24%), some students (8%) mentioned that the system did not contribute to their learning.

Table 4. Students' views on the entertainment level of the system.

Category	F	%
Fun	29	52.72
Learning by using the whole body	7	12.72
Learning by playing	7	12.72
Not fun	4	7.27
Learning unknown vocabulary items	3	5.45
Increasing motivation	3	5.45
Relaxing learning environment	2	3.63
Total	55	100

The following include examples of views of students of the system:

S2: It contributed to me because we play with our whole body, so it is more fun, and I can learn more quickly.
S4: It contributed because when we use our whole body, the words stay in mind.
S6: It contributed to me because I both learned and had fun.
S14: It contributed because the words became more permanent in my mind.
S26: It contributed to me. I learn very well when I use visuals and my body.

The students were asked whether learning English vocabulary through the kinesthetic learning system was fun or not, and the students' views on this issue were determined. The students' views are summarized in Table 4.

Table 4 shows that students found the kinesthetic learning system fun (52.72%), learned by using their whole body (12.72%), learned by playing games (12.72%), did not find the activities fun (7.27%), learned unfamiliar words (5.45%), increased their motivation (5.45%), and found the learning environment relaxing (3.63%).

The following include examples of views of students of the entertainment level of the system:

S3: It was a lot of fun because when I am moving, I get excited to learn, and I get excited when I am moving, and that's what makes it fun.
S6: I liked it very much because I am moving and it's a lot of fun.
S11: It was fun because, let's face it, a textbook lesson is a bit boring.
S13: Yes, because you are moving and learning English at the same time.
S17: It was fun because we are learning by playing games.
S23: I had fun because I was moving inside while doing it.
S29: I didn't think it was fun because we have weekly lessons in the books.
S33: It was fun because it made me understand the words better.
Ö34: It was fun because the pictures looked like a game to me. Or rather, it was fun because it was a game.
Ö36: It was a lot of fun because having fun and learning with friends is very nice.

Students were asked what they thought about the use of the kinesthetic learning system in other courses. Table 5 summarizes their views on the use of this application in other courses.

Table 6 reveals that students wanted the kinesthetic learning system to be used in mathematics (34.84%), Turkish (16.66%), science (13.63%), physical education (7.57%), social studies (7.57%), music (4.54%), arts (6.05%), and all courses (4.54%). The percentage of students who did not want it to be used in other courses was 4.54%.

Table 5. Views on the use of the kinesthetic learning system in other courses.

Category	f	%
Mathematics	23	34.84
Turkish	11	16.66
Science	9	13.63
Physical education	5	7.57
Social Studies	5	7.57
Music	3	4.54
Arts	4	6.05
All courses	3	4.54
I do not want to use it in other courses	3	4.54
Total	66	100

Table 6. Student views about the differences that distinguish the kinesthetic learning system application from other educational tools.

Category	f	%
Mobilizing the whole body	22	41.50
Learning by having fun with games	15	28.30
Ensuring attention and focus in the lesson	14	26.41
Not being boring	2	3.77
Total	53	100

The following include examples of students' views on the use of the kinesthetic learning system in other courses:

S2: I think mathematics is suitable for it. For example, we can mark the answer 2 + 2 = with our body.
S7: It can facilitate my learning in Turkish, mathematics, and science courses.
S11: In fact, I would like it to be used in all other courses except for only one drawing course (mathematics, Turkish, science, physical education, and social studies).
S18: I would like it in Turkish class because it would be more fun.
S24: I'd like to, especially if it's in math.
S27: I would like it to be prepared, especially for experiments in science class.
S32: Yes, I would like to, and I would like to do it in every course.
S33: I wouldn't want to because that's how I understand other subjects better.

Students were asked about the differences distinguishing the kinesthetic learning system application from other educational tools. Table 6 summarizes student views about the differences distinguishing the kinesthetic learning system application from other educational tools.

Table 6 shows that the activities mobilized students' whole bodies (41.50%), they learned by having fun with games (28.30%) and increased their attention and focus (26.41%), and the activities were not boring (3.77%).

The following include examples of students' views on the differences discriminating the kinesthetic learning system from other educational tools:

S2: It's different because we don't just use our hands; we do it with our whole body. I think that's the difference.
S4: We use our whole body, and the most significant difference is that it is very fun like a game.

S7: It is more fun and not boring. I have fun and learn even while waiting for my friends to do an activity.
S16: It is more fun than other English classes and it was very nice to mark with my foot without having to write.
S28: It made learning English words more fun, but I would have gotten bored if it was a blackboard or a textbook.
S33: I think the biggest difference is that it attracts our attention. For example, when we get bored of sitting, we cannot pay attention to the lesson. In this method, we did the lesson by jumping while standing so we could pay attention to the lesson with this method.
S35: Because in the other lessons, the mind and intelligence are used. In this one, our whole body is actively involved in the lesson.
S38: It's on the ground, and it's playful, so it stands out from other vehicles. I think it's a lot of fun.

4. Discussion

This study implemented an immersive and interactive English language learning environment projected onto a large classroom floor. To ensure accurate interaction between students and the projected content, we tackled two key challenges: pixel distortion and shadow interference. Initially, a pixel distortion approach was considered but abandoned due to limitations in its scalability and accuracy. Instead, we opted for determining participants' real-time three-dimensional coordinates (X, Y, and Z) utilizing a depth camera. The Kinect One camera, the most widely used camera on the market, was chosen to identify user positions and bodily movements, overcoming the limitations of traditional pixel-based interactions. Additionally, the camera's high frame rate (30 fps) ensured smooth and responsive gameplay within the projected area. This approach effectively mitigated shadow interference, a potential issue with projected floor displays. By directly tracking individual body positions rather than relying on pixel analysis, the system disregarded shadows cast by users, preventing inaccurate inputs and ensuring reliable interaction with the learning content.

While the existing literature on interactive learning games is limited, several studies offer relevant comparisons. Si et al. (2013) [32] employed a Kinect sensor-based system for Chinese language education, transitioning away from traditional keyboard–mouse and touch screens. The virtual environments created in the study only worked with a computer interface however, and they remained confined to the computer screen, limiting opportunities for physical activity. In the sports field, Düking et al. (2016) [34] used a system to improve and measure the agility values of athletes by applying contact plates to certain parts of the floor. In this system, the athlete sees which contact plates to go to on the television screen in front of him/her. However, our system employed projected images instead of contact plates, allowing for easier manipulation and flexibility in pattern and object design. This eliminates limitations on the number and complexity of elements within the learning environment. By incorporating physical movement and interaction with projected images, our system encourages active participation and potentially enhances student engagement compared to screen-based solutions. In addition, our system facilitates collaborative learning through its multi-user functionality, enabling group activities and fostering social interaction within the learning process.

Following the system development and pre-testing phase, the application phase was implemented. Upon completion, post-test achievement assessments were administered to both the experimental and control groups, and qualitative data were collected through student interviews. Analysis of pre-test scores revealed no significant differences between the groups. However, post-test results demonstrated a marked improvement in the experimental group compared to the control group ($p < 0.001$), indicating a positive impact of the kinesthetic learning system on learning outcomes. This finding was further corroborated by a significant group-by-time interaction effect (F: 9.166, $p < 0.003$), suggesting that the intervention specifically influenced the trajectory of learning over time. Qualitative data gleaned from student interviews offered valuable insights into the students' experiences with the system. Participants reported faster learning, enhanced vocabulary retention, increased enjoyment of learning activities, improved focus and attention during lessons, and a positive perception of the system's contribution to their learning. Notably, students perceived the system as facilitating learning through both game-based elements and physical movement. Additionally, they expressed a desire for similar systems to be implemented in other subjects, including mathematics, Turkish, and science. Similar to this study, studies in which the Kinect system was used for teaching purposes concluded that it was much more effective than classical teaching methods with a significant difference, especially in English language teaching [30,31]. Shakroum, Wong, and Fung (2018) [35] found that a gesture-based learning system with a Kinect sensor (GBLS) positively affected students' intrinsic motivation. Hsu (2011) reported that XBOX Kinect, as a learning tool, can potentially increase student motivation and create a pleasant classroom environment. Zhang (2012) [29] reported that Kinect allows students to communicate more with games through their own movements. In almost all of the studies in the literature where the Kinect sensor was used for educational purposes, the participants were involved in games with a television screen on the opposite side in 3D. In addition, they realized data flow with their hands without moving too much from their position. This leads to movement limitation and cannot reflect real movements. Therefore, both the motivation and focus of individuals and kinesthetic learning will remain limited. However, in this study, the participants moved in a 4 $\times$ 3 m area and provided the data flow with their feet. The qualitative data and video recordings show that the students' focus and enjoyment levels were very high. These levels were directly reflected in the achievement test results.

Numerous studies in the existing literature indirectly support the findings of this research, demonstrating that kinesthetic learning contributes to increased active engagement in English as a second language (ESL) classes [36,37]. Additionally, multiple investigations have found that kinesthetic learning fosters active participation among ESL students in various activities [38]. A study by Brady et al. [39] reported that engaging in physically active classroom lessons could enhance students' comprehension of the content, aiding in long-term retention. Beyond academic achievement, integrating movement may be beneficial for students facing challenges in grasping academic content. The observed enhancement in academic performance and positive student attitudes align with the existing literature, suggesting that the kinesthetic approach influences the brain, thereby improving learning and cognitive functions. The positive impact of physical activity on memory, learning, anxiety, stress, depression, and attention deficit is evident, all of which significantly affect students' academic performance [40–42]. Research indicates a connection between the brain region associated with "body learning" and cognitive processes, highlighting the natural stimulant effect of exercise, play, and activity on circulatory and neurovascular systems [14]. Ratey [43] further reported that physical activity enhances learning by optimizing mindsets for improved alertness, attention, and motivation, promoting the connection of nerve cells in response to new information, and fostering the development of stem cells into nerve cells for efficient internal information transfer.

However, a notable limitation of this system is its dependency on sufficient classroom space for the projection onto the floor. Its applicability is constrained in classrooms with limited space and areas featuring a multicolored background. Another drawback is the necessity for a high-resolution projection device and depth camera. Additionally, crowded classrooms may impede student rotation and complicate classroom management.

5. Conclusions

This study investigated the efficacy of a novel "Projection-Based Kinesthetic English Language Learning Module" in promoting second language learning. The experimental group engaging with the interactive learning environment demonstrated significantly greater improvement in post-test scores compared to the control group, indicating enhanced learning outcomes. Furthermore, group-by-time interaction analysis revealed a statistically significant interaction effect, suggesting the intervention's specific impact on learning trajectory. Qualitative data from student interviews corroborated the quantitative findings, highlighting self-reported faster learning, vocabulary acquisition, increased enjoyment, and improved focus during lessons. These findings collectively support the potential of kinesthetic, immersive learning environments in facilitating English language acquisition.

While acknowledging this study's limitations, we recommend utilizing this module as an active learning tool to complement traditional second language instruction. Additionally, student feedback points toward the potential application of similar software in diverse educational domains, including mathematics, science, and preschool education. Further research could explore the efficacy of such systems in promoting cognitive development in elderly populations and enhancing motor skills in sports training. In conclusion, this study offers valuable insights into the benefits of kinesthetic interaction for language learning, paving the way for further exploration of immersive technologies in educational settings.

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