ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 11, Issue 6, June 2024

An AI-Based Serious Mobile Game to Assist Learning between Turkish and English Languages

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Abstract*— Globalization impacts various aspects of society, from demographics to culture and politics, making proficiency in a second language essential for job searching and communication. However, students face challenges, such as limited vocabulary, which hinder learning and fluency in the new language. To address this issue, a serious game for mobile devices was developed in Unity 3D, employing Mobile Learning, Digital Game-Based Learning, Software Engineering, and Artificial Intelligence concepts. This game utilizes an AI-based model to adjust the game difficulty dynamically according to the user's performance. A trial was conducted with 25 students over 30 days, divided into control and test groups. The control group played the game only three days at the beginning and end of the trial period, while the test group played it frequently throughout the 30 days. It was expected that, by the end of the period, the test group, having used the game more, would show better results and a significant increase in their vocabulary compared to the control group. The test group students achieved a 65.12% higher score than the control group students at the end of the test period. This indicates an improvement of 43.60% with respect to the results at the beginning the test period, thus demonstrating the effectiveness of the game as a learning tool for Turkish and English.

***Index Terms*— AI-based, Artificial Intelligence, Digital Game-Based Learning, English, Mobile Game, Mobile Learning, Serious Game, Software Engineering, Turkish, Unity 3D.**

I. INTRODUCTION

In the current era of globalization, which profoundly impacts demographic, cultural, political, and social aspects worldwide, the necessity of acquiring a second language has become increasingly apparent, particularly for tasks like job seeking and information sharing [1] [2] [3]. However, language learners often encounter challenges, primarily stemming from limited vocabulary, which hampers their abilities in reading, writing, listening, and speaking [4]. Recognizing the effectiveness of video games as learning tools, there's a proposal to harness mobile phones as productive distractions for students during downtime between classes, as well as study aids for Turkish and English language acquisition [5].

The present study aims to evaluate whether the development of a serious mobile game in Unity 3D using concepts from Mobile Learning, Digital Game-Based Learning, Software Engineering, and Artificial Intelligence serves as a supportive tool for learning Turkish and English.

II. LITERATURE BACKGROUND

A. Previous Similar Researches

Studies demonstrate that despite some limitations, students utilizing video games as language learning tools maintain positive attitudes towards their efficacy, indicating potential benefits for skill enhancement and vocabulary acquisition, warranting further investigation in the field [6]. Moreover, research focusing on the integration of video games into Malay language education highlights their potential applicability in higher education, advocating for the development of technology to enhance language learning engagement and interactivity across academic institutions [7]. Similarly, findings suggest that video games can aid vocabulary development for speakers of various languages, though additional research is necessary to fully comprehend their impact across different educational contexts [8]. In the realm of serious games, investigations indicate a plethora of pedagogical opportunities, particularly for language learning, facilitated by mobile devices, tablets, and laptops, enabling individualized and cooperative learning both inside and outside the classroom. These studies advocate for empirical research on serious games' efficacy in foreign language education, emphasizing motivation as a key determinant of learning outcomes [9] . Moreover, the rise of Artificial Intelligence (AI) has significantly impacted educational institutions, enhancing teaching effectiveness and efficiency while fostering personalized learning experiences tailored to students' needs and abilities, ultimately enriching instructional quality and learning outcomes [10].

B. Serious Games

Serious Games are interactive activities crafted to provide entertainment while also serving as platforms for learning, education, and training in specific areas and tasks. In contrast to conventional teaching methods, which are often teacher-centric, Serious Games adopt a learner-centered approach, empowering participants to take control of their

ISSN (Online) 2456 -1304
International Journal of Science, Engineering and Management (IJSEM)
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interactive learning journey [11]. This approach fosters active and critical learning experiences. Serious video games used for language learning purposes have demonstrated the capacity to enhance vocabulary acquisition, particularly when learners encounter target words repeatedly, ideally more than six times, and within contexts offering rich contextual cues [12].

C. Artificial Intelligence

Artificial Intelligence (AI) can be defined as the behavior exhibited by a machine that, if performed by a human, would be deemed intelligent. Expanding on this definition is challenging due to the ambiguity surrounding the defining factors of human intelligence [13]. AI can serve as a pivotal tool in the development of Serious Games, particularly in modeling the Player Experience. This capability is invaluable for educators, enabling them to assess students' progress and determine if additional support is needed. However, it's important to note that AI-driven assessments in Serious Games lack the subjective elements of teacher-student relationships and trust, relying instead on consistent records of computerized events and judgments. Consequently, qualitative aspects of teaching and learning may be overshadowed by quantifiable metrics [14].

D. Machine Learning

It is an implementation of Artificial Intelligence. It is one way a computer assimilates data or states and provides a learned solution or response. Artificial Intelligence is often thought of as a broader term reflecting an "intelligent" system. A full-game Artificial Intelligence system, for example, may incorporate machine learning tools combined with more classic Artificial Intelligence such as behavior trees [15].

E. Unity 3D & ML-Agents

Unity 3D, developed by Unity Technologies, is a versatile tool primarily used for creating video games. Its Editor is compatible with Microsoft Windows, Mac OS, and Linux, allowing for broad accessibility. Games made in Unity have the flexibility to run across multiple platforms, including PCs, mobile devices, and gaming consoles. Developers utilize the C# programming language within Unity's programming editor to implement game resources. Moreover, Unity can be seamlessly integrated with various other applications like Blender, 3D Max, Maya, ZBrush, Cinema 4D, Adobe Photoshop, among others [16]. Additionally, ML-Agents, a package integrated with Unity, empowers developers to build Machine Learning models for learning and simulating behaviors in diverse environments. Through the creation of Agents equipped with Brains trainable via C# Scripts, developers can indirectly guide their behavior using Reward systems, Observers, Actions, and Decisions [15].

F. Firebase Authentication & Cloud Firestore

Firebase is an app development platform offering a range of solutions for building apps and games [17]. Firebase Authentication, a component of Firebase, provides backend services, a Unity 3D SDK, and UI libraries for user authentication, supporting various methods such as passwords, phone numbers, and federated identity providers like Google and Facebook. It seamlessly integrates with other Firebase services and industry standards like OAuth 2.0 and OpenID Connect, facilitating integration with custom backends [18]. Another tool, Cloud Firestore, is a flexible and scalable NoSQL cloud database service built on Google Cloud. It enables storing and syncing data for client-side and server-side development, particularly for mobile, web, Firebase, and Google Cloud server development. Cloud Firestore ensures data synchronization in client applications through real-time listeners and offers offline support for mobile and web devices, enabling responsive applications regardless of network latency or internet connectivity [19].

G. Digital Game-Based Learning

Video games, beyond their entertainment value, serve as potent educational tools, offering novel opportunities for effective learning. Game-based learning recognizes the digital-native nature of today's students, who have grown up immersed in technology, including video games, necessitating new motivational strategies. Unlike traditional education methods reliant on external factors like punishments and rewards, games captivate learners through a unique blend of enjoyable experiences, immersive participation, clear objectives, interactivity, adaptability, feedback mechanisms, and elements like competition and challenge [20]. While learning games face criticism regarding their effectiveness, any shortcomings typically stem from design flaws rather than inherent limitations of the approach [20].

H. Mobile Learning

The future of learning revolves around four key pillars: mobility, interaction, artificial intelligence, and technology-based resources like augmented reality and educational games. These elements intersect to create a dynamic model of learning characterized by mobility, interactivity, and intelligence, utilizing all available spaces and times for learners. As technological integration becomes increasingly prevalent, there's a need to enhance mobile technology and adapt teaching methods to leverage new forms of interaction and learning. This involves developing technologies that capitalize on mobile capabilities and exploring innovative teaching and learning models to improve students' content assimilation levels [21].

I. MDA Framework

The MDA framework defines game components in a cohesive manner, delineating Mechanics as the rules and

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

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components dictating player actions or system processes, which directly influence Dynamics, illustrating how these rules unfold in gameplay through player input and interactions [22]. This interaction between Mechanics and Dynamics aims to evoke specific emotional responses from users, forming the basis of Aesthetics, which encapsulates the desired emotional experiences generated during user interaction with the gamified system [22]. Thus, Mechanics inform Dynamics, which in turn influences Aesthetics, ultimately shaping the overall user experience within the game environment [22].

III. METHODOLOGY

A. Exploration of Technologies for Development

The realization of this project would be facilitated by several technologies. One notable tool is the Unity 3D game development engine, known for its versatility in creating cross-platform projects using the C# programming language. Additionally, the availability of an easily integrable library for Artificial Intelligence called ML-Agents within Unity enables the training of AI models using Machine Learning. This library allows for the creation and implementation of AI brains within the video game, as well as graphical monitoring of the AI agent's behavior during the training period.

Another technology worth mentioning is Google's Firebase library and services. Through Firebase Authentication, users can log in to the video game, while Firestore Database facilitates the registration and storage of relevant user information. Moreover, Firebase services are free for the expected number of users for this study and operate in real-time, enabling continuous monitoring of results.

Various previous studies provided recommendations and insights into methodologies and technologies relevant to this project. These studies were instrumental in designing the methodology for the current project.

B. Game design within the framework of Software Engineering

In the realm of software engineering, the Use Case diagram serves as a foundational framework for designing the game mechanics. This diagram visually represents the interactions between different systemactors and use cases.

Given the educational component inherent in serious games, as well as the emphasis on motivation highlighted in previous studies, the game mechanics need to be simple yet engaging, primarily avoiding negative stimuli and instead promoting positive ones. This necessitates a cohesive connection between the implemented mechanics, dynamics, and aesthetics.

C. Game design withing the framework of User Interfaces

The user interface component is crucial in serious game design, as it is the primary means through which users interact with the game. Therefore, a simple user interface with soft pastel colors and rounded edges is preferred to avoid negative stimuli. A cartoonish overall style is adopted to make users feel like they are playing a game rather than undergoing an exam, enhancing engagement and enjoyment.

D. Game Mechanics

The player starts a game with an initial time of 30 seconds which will decrease over time. Firstly, a Turkish word is presented to them, which serves as the question, followed by the word's proficiency level ranging from level A1 to level B2, and its category, all intended to provide hints and context.

Below this, the user is presented with 4 answer options, one of which corresponds to the English translation of the word, while the other three are incorrect options, as shown in **Illustration 1**.

Illustration 1 Main Mechanic User Interface Panel.

The game progresses as the player answers questions; correct answers earn time bonuses to extend the game duration and points representing the number of correct answers. However, incorrect answers result in time penalties, shortening the game.

The difficulty of the video game increases or decreases depending on the number of correct or incorrect answers the player provides. This difficulty level is calculated by an Artificial Intelligence brain, which makes decisions based on the player's performance.

When the player answers incorrectly, the video game displays the correct answer to reinforce learning as shown in the **Illustration 2** (right), and when answered correctly, it

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

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provides positive feedback through words and sounds, as shown in the **Illustration 2** (left). Every five answers, one of the incorrectly answered words (if any) is displayed again.

Illustration 2 Answer Status Panel when Player answers correctly (left) and incorrectly (right).

E. Video Game Implementation

There are two main scripts responsible for the game mechanics: one is responsible for managing the level, called Level Manager, and the other is responsible for interaction with the artificial intelligence agent, called Teacher Agent.

When the game mechanics are initiated, the two main parts begin execution. The first part handles time management, and the second part manages the question mechanics.

For the time management mechanics, there is a method that subtracts the elapsed time from the remaining game time and validates if the player still has available game time. If the player has no available game time, the Game Over Panel is displayed, thus ending the game. As shown in the **Illustration 3**.

For the question mechanics, there is an iterative algorithm that repeats while the player has game time as follows:

At the start of the game, the Fill Word Relations method is executed, which loads the word database in Turkish and English into memory. Subsequently, the local database is cleared (since it is used to save the results of each game). Once this is done, the Set Game Parameters method is called to adjust the initial characteristics of the game, such as the initial time. Finally, the Request Action method is called, which is an invocation to an external method where interaction with the Teacher Agent begins.

Illustration 3 Game Over User Interface Panel.

Once the invocation is made, the Teacher Agent executes the On Action Received event where, depending on the training parameters of the artificial intelligence brain, the level of the game is calculated through the Select Current Word Level method, the previous level is incremented, the total number of words shown is incremented, and finally, the Generate Random Question method of the Level Manager is called.

The Generate Random Question method is the main method where, depending on the values generated by the artificial intelligence brain, the question ID to be shown to the player is calculated. Additionally, it stores some necessary counters such as the total number of words shown and a counter of questions shown before showing a previous error. If required, the mechanics will call the Generate Previous Error method to show a previous error of the player. If not, it will call the Generate Normal Question method, where based on the question level generated by the Teacher Agent, it will generate a random ID from the question list. Once this is done, it will use this parameter to display it in the user interface and generate the corresponding values for the correct answer and incorrect answers, assigning these to the response buttons of the user interface.

Once this is done, player action is required, which, by clicking on one of the response buttons, will activate the Set Answer method where it will be validated if the response was correct or not. If the response was correct, the Set Answer as Correct method will be called, where the relevant time and score bonus will be applied, a counter with the correct answers will be incremented and saved, and the correct answer panel will be shown. On the other hand, if the response was incorrect, the punishment in time and relevant

ISSN (Online) 2456 -1304
International Journal of Science, Engineering and Management (IJSEM)
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score will be applied, the counter of incorrect answers will be incremented, and the incorrect answer panel will be shown.

Once this is finished, the Save Word Relation Values method is executed, where the result of the current question is stored in the local database, incrementing the counter of correct or incorrect answers (depending on the case), calculating the Hit Rate, Error Rate, among others.

Finally, the Generate Question method is executed, which through a counter of actions made by the Teacher Agent, calculates if a decision is required by the Teacher Agent. If so, the Request Decision method is executed, which informs the artificial intelligence brain that it needs to make a decision and then execute the On Action Received method. If not, the Generate Random Question method is executed, and the cycle begins again.

F. Artificial Intelligence Model Training

During the training phase of the Teacher Agent, a similar mechanic was implemented; however, instead of directly interacting with a student, it interacts with an automated mechanism simulating the behavior of various types of students, providing a response in each frame to streamline the training process.

During the model training period, each student simulator is equipped with an Artificial Intelligence Agent. This is done to train the model based on different types of behaviors simultaneously, aiming to achieve better results in a shorter training period.

Similar to the main mechanic, there are two primary threads. The first is the "Manage Time" method, responsible for handling the game's time, and triggering the "Activate Game Over Panel" method if the game has ended. However, practically, no panel is shown as there is no real student; instead, the game is reset to continue the training.

The second method is responsible for displaying different questions. This sequence of methods is executed similarly to the main game mechanic, calling the "Fill Word Relations," "Reset Local Database," and "Set Game Parameters" methods to prepare the start of the game, as explained earlier. Following this, the "Request Action" method is called, directly invoking the "On Action Received" event of the Teacher Agent. Similarly to the main mechanic, it calls the "Set Current Word Level" method to assign a game level. This time, instead of calling the main mechanic and waiting for a response from the student, it calls the "Ask to Student Model" method, which returns a boolean value depending on whether the student model responded correctly or not. Based on this response, the model is rewarded or penalized accordingly.

The expected behavior by the Teacher Agent is for the student to remain playing for the longest time possible. It is rewarded when it assigns an appropriate difficulty level for the student and penalized when the difficulty level is not appropriate. Once this is done, the process is repeated, and training continues until maximum values are reached in the Cumulative Reward.

Since the artificial intelligence brain being trained cannot make decisions for the student but simply acts as a guide managing the game's difficulty level, it cannot be rewarded or punished based on the student's response results. Instead, it should be rewarded or punished based on the chosen difficulty level, considering certain established parameters: The success rate of responses is compared with a minimum acceptable success rate and a maximum acceptable success rate, the previously chosen level is compared with the currently chosen level and the chosen difficulty level is compared with the maximum possible difficulty level. Based on these comparisons, the artificial intelligence is rewarded or punished.

The Artificial Intelligence needs to gather information by observing the behavior of certain outcome variables, to adapt and seek the optimal result. In this case, the Agent needs to observe the student's behavior to decide the difficulty level of the game.

After several tests, it was concluded that only an observer pointing towards the student's Hit Rate was needed since the other values (response history, error percentage, response result, etc.) directly depend on this.

To train the model, an implementation of a method simulating the basic behavior of a student was required, generating a Boolean response. It returns true if the response was correct, and false if it was incorrect.

The method takes as input the number of times the question has been shown and the number of correct responses. This is to simulate the student's learning curve when repeatedly seeing the same word.

There are several types of students for training: The bad student, who will always make mistakes in responses, the normal student, whose success rate will increase through a curve as the number of correct responses and the number of times a word is shown increase, the good student, who will always respond correctly to questions and the random student, who will respond randomly to all questions.

The model was trained in this way so that the behavior of the artificial intelligence brain is prepared for different types of behaviors, as not all students will behave in the same way or be at the same level.

IV. EXPERIMENTS AND RESULTS

A. Tests with Students

During a 30-day period, a controlled experimental investigation was conducted using quantitative data collected while volunteers selected from students learning Turkish at the TOMER Institute of Gazi University played a tested mobile game. Students wishing to participate voluntarily in the research were divided into two groups, experimental and control, matched for population and demographic characteristics. Participants in the control group were entitled to play the tested game only for a maximum of 3 days at the

ISSN (Online) 2456 -1304

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beginning and end of the research, with a limit of 20 games each time. Outside of this interval, the game system was blocked, and the control group was not allowed to play at all, allowing for the measurement of independent progress from the tested game during the research period. Participants in the experimental group were able to play the game unlimitedly throughout the research period, allowing for progress measurement through the tested game during the research period.

To participate in the research, a minimum of 20 students receiving Turkish education at the TOMER Institute of Gazi University were requested to volunteer, of which 25 students participated, 13 in the experimental group and 12 in the control group. The distribution of information corresponding to each of the participating groups is organized as follows: age, gender (M for Male, F for Female), Country of origin, native language, and level of education they will enter upon completion of their Turkish studies. The **Table 1** and Table 2 correspond to the information of the test group and the control group respectively.

Table 1 Test Group Information Distribution.

Age	Gender	Country	M. Tongue	E. Level
17	F	Irak	Arabic	Bachelor
18	F	Egypt	Arabic	Bachelor
18	F	Syria	Arabic	Bachelor
18	M	Palestine	Arabic	Bachelor
18	M	Palestine	Arabic	Bachelor
19	F	Montenegro	Montenegrin	Bachelor
20	M	Tunisia	Arabic	Bachelor
20	M	Turkmenistan	Russian	Bachelor
21	M	South Africa	English	Bachelor
21	M	Turkmenistan	Turkmen	Bachelor
23	M	Cambodia	Khmer	Master
28	M	Bangladesh	Bengali	Doctorate
30	M	Uganda	Luganda	Doctorate

Table 2 Control Group Information Distribution.

Age	Gender	Country	M. Tongue	E. Level
18	F	Kazakhstan	Russian	Bachelor
18	F	Nigeria	Yoruba	Bachelor
18	F	Palestine	Arabic	Bachelor
18	M	Jordan	Arabic	Bachelor
18	M	Russia	Russian	Bachelor
19	F	Irak	Arabic	Bachelor
19	M	Honduras	Spanish	Bachelor
19	M	Venezuela	Spanish	Bachelor
21	M	Turkmenistan	Turkmen	Bachelor
22	M	Djibouti	Somali	Master
24	M	Rwanda	Kinyarwanda	Master
26	F	Kenya	Luo	Master

Each student participating in the research had to possess an Android-based mobile device and register with their email address by downloading the video game called "Master Kelime" from the Google Play Store. The gaming statistics of each student (date, score, number of correct answers, number of incorrect answers, game duration, maximum level, average level) were automatically recorded and stored in a database for further analysis.

At the beginning of the research process, demographic data of the volunteer students, such as age, gender, country, native language, and educational level, along with the email address they would use to play, were collected through a brief information form. The email address was used solely to identify students as game users in the database and to relate students' demographic data to the quantitative data collected from the games. The collection of this data was carried out directly at the TOMER Institute of Gazi University after informing the students about the research and obtaining their voluntary consent to participate.

In addition to the demographic data collected through a brief form at the beginning of the research process, quantitative data obtained through the game were transferred directly from the game side to a database created for the game. Each game played by a participating user automatically included a unique game identification associated with the player's email address, as well as data such as game duration, score, displayed words, number of correct and incorrect answers, and maximum and average levels, which were sent to Firebase's Cloud Firestore service and securely stored without authorized external access.

B. Analysis of Results

Table 3 displays the total results obtained by each group and the difference between them. These results are categorized into parameters corresponding to the number of users in each group, the number of games played, the total score obtained, the total number of words displayed, the total number of correct answers, the percentage of correct answers, the total number of errors, the percentage of errors, and the total amount of time played.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

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Table 3 Results generated from all games taking the daily data obtained.

Parameter	Test	Control	Difference
Users	13	12	8.33%
Games	210	34	517.65%
T. Score	4022	675	495.85%
T. Showed	5487	859	538.77%
T. Hits	4137	689	500.44%
T. Errors	1134	135	740.00%
T. Time	348.82	57.22	509.61%

For the **Table 3** it's evident that, overall, users in the test group played approximately 517.65% more than those in the control group. They also scored 495.85% higher during the games, encountered roughly 538.77% more words, obtained 500.44% more words answered correctly, and spent 509.61% more time playing. However, they also obtained 740% more errors.

Table 4 presents the average total results obtained, organized by day with the sum of the results obtained in a day taken as the daily results. This is done to have a clear understanding of the overall daily performance of the users. Similarly, they are organized by group with the difference between them, and these results are categorized into parameters in the same manner as Table 3.

Now, for the **Table 4** it's noticeable that the test group scored 6.67% higher, encountered 15.12% more words, guessed 7.25% more questions correctly and played 10.05% more time during the games. However, they made 51.85% more errors. This indicates that students in the test group performed better in terms of scoring points and answering questions correctly, but they also made more errors compared to the control group.

Table 4 Results generated by taking all the sum of the data obtained in one day's games as the daily game.

Parameter	Test	Control	Difference
Users	13	12	8.33%
Games	28	5	460.00%
T. Score	144	135	6.67%
T. Showed	198	172	15.12%
T. Hits	148	138	7.25%
T. Errors	41	27	51.85%
T. Time	12.59	11.44	10.05%

In **Table 5**, the average results obtained by the test group students at the beginning and at the end (i.e. during the first 3 and last 3 days) of the testing period are presented, employing the same aforementioned method of aggregating all daily items into a single item to obtain the total daily result, while also disregarding results and days where students did not engage in any activity.

Table 5 Comparison between the initial and final days of the Test Group results.

	Initial	Final	Dif.
T. Score	44.33	71	60.15%
T. Showed	55	90	63.64%
T. Hits	44.33	71	60.15%
T. Errors	9.67	18	86.21%
T. Time	193.67	286	47.68%

As can be observed in **Table 5**, students in the control group exhibited superior performance at the end of the test period across all parameters, scoring 60.15% more, encountering 63.64% more words, answering 60.15% more questions correctly, while also committing 86.21% more errors and spending 47.68% more time on the tasks.

Table 6 displays the average results obtained by the control group students at the beginning and at the end (i.e. during the first 3 and last 3 days) of the testing period, following the same methodology as employed in **Table 5**.

Table 6 Comparison between the initial and final days of the Control Group results.

	Initial	Final	Dif.
T. Score	30.5	43	40.98%
T. Showed	35.5	58	63.38%
T. Hits	30.5	44	44.26%
T. Errors	4	13	225.00%
T. Time	150	187	24.67%

As evident from **Table 6**, students in the control group also demonstrated better performance at the end of the test period across all parameters, scoring 40.98% more, encountering 63.38% more words, answering 44.26% more questions correctly, while also committing 225.00% more errors and spending 24.67% more time on the tasks.

Table 7 Comparison between the initial and final differences.

	Initial Dif.	Final Dif.	Comp.
T. Score	45.34%	65.12%	43.60%
T. Showed	54.93%	55.17%	0.44%
T. Hits	45.34%	61.36%	35.33%
T. Errors	141.75%	38.46%	-72.87%
T. Time	29.11%	52.94%	81.85%

Comparing the two groups (**Table 7**), at the beginning of the testing period, the test group obtained 45.34% more points, encountered 54.93% more words, answered 45.34% more questions correctly, while also spending 29.11% more time on the tasks. However, they also made 141.75% times more errors. Additionally, at the end of the testing period, the test group scored 65.12% more, corresponding to a 43.60% improvement compared to the initial testing period results, encountered 55.17% more words, answered 61.36% more questions correctly, corresponding to a 35.33% improvement compared to the initial testing period results, and spent 52.94% more time playing, corresponding to an 81.85% increase compared to the initial testing period results. However, they just made 38.46% more errors, corresponding to an improvement in -72.87% (decrease in errors) comparing to the initial period.

V. LIMITATIONS OF THE RESEARCH

During the development phase, unforeseen circumstances like abrupt exits from the game and interruptions were not accounted for, leading to potential data loss from incomplete sessions. Also, a significant obstacle emerged - many students at Gazi University's TÖMER were not Android users, limiting participation.

Additionally, the heavy workload of Turkish language-related topics for TÖMER students may have dampened their motivation to engage fully.

Motivation among students to play games daily was lacking, necessitating reminders via email and in-person interactions. Moreover, some participants only engaged sporadically, primarily at the beginning and end of the testing phase, leading to their transfer to the control group.

Analysis of the data revealed a preference among students for shorter, multiple gaming sessions to maximize points. However, challenges persisted, such as contacting absent students and accommodating varying classroom schedules during the testing period.

Furthermore, unforeseen circumstances like exam periods and holidays were not considered during scheduling, impacting participation. Additionally, a significant portion of registered participants did not meet the study's requirements, further complicating data collection.

Despite the application's intended purpose as a vocabulary learning tool between Turkish and English, some participants lacked proficiency in English, potentially affecting their engagement and outcomes. These challenges underscore the need for more comprehensive planning and adaptability in future studies.

VI. CONCLUSION

Based on the data collected during the testing period, it can be concluded that students in the test group obtained a 45.34% higher score than the control group students in the initial period, and in the final period, they achieved a 65.12% higher score. This indicates an improvement of 43.60%, suggesting that the video game functions as a tool for learning Turkish and English languages.

The application encourages students to practice their Turkish vocabulary by adding approximately 26.83 minutes of study time per student in the test group.

Students in the test group were able to see more words, indicating that their game sessions were longer than those of the control group.

Students in the test group made more errors, suggesting two scenarios: either the application is not providing the necessary feedback for users to memorize the word, or the application has too many words, making it difficult for words to be repeated with the necessary frequency between game sessions for memorization.

Despite having a lower accuracy rate, students in the control group overall managed to achieve a greater number of correct answers.

Students in the test group used the application approximately 6 times more than the control group, suggesting that the improvement in results depends directly on the number of game sessions and the time spent in each of them.

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