

Fun Tac Toe: A Multi-platform Game-based Learning Approach Integrating Trivia with Classic Gameplay

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Abstract: Game-Based Learning (GBL) has proved to be an efficient approach for motivating learners and improving educational performance. However, current educational games are prone to fall into one of two categories: immersive and highly sophisticated learning tools or simplistic quiz applications which lack interaction opportunities. Thus, there is a need to design new educational games with lightweight and easy-to-use interface. This paper presents Fun Tac Toe, a multiplatform educational game that combines trivia-based learning elements with the rules of classic Tic-Tac-Toe. In particular, users will have to provide correct answers to knowledge-based questions before marking a cell. The proposed design will help learners to practice retrieval, get instant feedback, stay involved in learning and participate in an interactive experience at the same time. The system is implemented using Flutter and Firebase, providing a scalable architecture that supports mobile, web, and desktop platforms together with real-time multiplayer functionality. The category-based design also enables it to be adapted easily to different educational subjects while preserving the same gameplay mechanics. An initial classroom deployment shows the feasibility of integrating this platform in education at the level of undergraduate teaching and is accompanied by an evaluation framework that considers academic performance, learner engagement, usability, and interaction patterns. The preliminary deployment provides encouraging evidence regarding classroom integration while establishing a foundation for larger controlled experiments. Overall, the paper demonstrates how game mechanics could be utilized for creating accessible and scalable educational experiences, providing researchers with foundation for further research in the area of game-based learning.

Keywords: Game-based learning, Educational games, Retrieval practice, Interactive learning, Multi-platform learning

1. Introduction

Educational technologies have been transformed by digitalization in recent years and brought about various innovative ways to deliver educational content. In turn, Game-Based Learning (GBL) solutions have emerged as one of the most promising techniques for motivating students and helping them to acquire new skills in more efficient ways. However, designing effective systems that are readily available at the same time poses many challenges and needs further investigation.

One of the frequent issues when creating educational games is choosing between highly immersive games with advanced narrative, complex interaction models, etc., and simple quiz-type educational games that provide easy access and little interaction. Whereas immersive games may engage the user by offering a variety of experiences and entertainment options, they usually require a lot of effort from the part of the learner before the educational content is absorbed. On the other hand, although there are many different trivia-based quizzes that offer basic interaction, it might not be sufficient enough to keep a learner motivated for a longer period of time.

As far as the latter option is concerned, however, there is a possibility to design a game-based learning model which would incorporate an interesting interaction pattern but would still be accessible for users.

In this work, Fun Tac Toe is introduced as an educational game based on the traditional game of Tic-Tac-Toe which includes elements of trivia-based learning within its core interaction pattern. In the process, the player receives a knowledge-based question which has to be answered correctly in order to make a move, thus turning a simple game into an effective learning system that encourages retrieval-based learning, provides instant feedback and maintains engagement for a longer period of time.

The choice of Tic Tac Toe as the basis for the game design was intentional because of several reasons. Firstly, it has an understandable set of rules which makes it easy to play and secondly, due to its simplicity and the fact that it is quite short-lived, learners will be able to focus on solving educational problems during gameplay without any extra distractions.

The application itself was created using Flutter for a multiplatform deployment which means that it runs on mobile, web and desktop platforms and includes such features as user authentication, real-time communication, and content management. Furthermore, the content is highly customizable according to different subject areas via configuration files.

Overall, the current project has several key contributions to the field of educational game design. They include: a novel approach to designing lightweight game-based learning systems by incorporating knowledge tests

directly into gameplay, a proof-of-concept implementation on multiple platforms, and an empirical evaluation framework.

The paper is structured as the following; Section 2 gives an overview of relevant literature. Section 3 explains the design of the educational game. Section 4 describes implementation aspects. Section 5 outlines the evaluation framework and future deployment plan. Educational implications are discussed in Section 6. Conclusion and future work are discussed in Section 7.

2. Related Work

The topic of Game-Based Learning (GBL) has become highly prevalent in the context of contemporary educational technologies due to their capacity to motivate and engage learners as well as boost academic performance. Based on systematic literature reviews, educational games prove beneficial to learning outcomes only if gaming is deeply integrated with education and cannot serve as entertainment alone (Boyle et al., 2016; Khaldi et al., 2023; Tene et al., 2025). For the higher education setting, where time-efficiency and access to resources play a crucial role, lighter game-based applications may provide certain advantages over heavy immersive learning experiences.

One of the key issues related to the implementation of GBL solutions is finding a balance between engagement and educational effect. Whereas immersion in educational games enhances learner involvement, excessive cognitive load caused by complicated game mechanics may hinder this process. According to Plass et al. (2015), effective application of game-based learning is impossible without a balanced combination of gameplay mechanics, instruction, and learners' cognitive functions. Later research supports the idea that usability, clarity, and relevance to educational goals remain essential factors of success in gamifying educational experiences (Henry et al., 2024; Abou Hashish, 2024).

The idea of gamification became highly popular due to its ability to engage users through various game elements like points, badges, rewards, and competitive feedback (Deterding et al., 2011). The use of external motivators is common in numerous digital learning tools. However, research shows that unless these motivators are linked to meaningful educational activities, they do not contribute to meaningful learning experiences (Deci and Ryan, 2000; Khaldi et al., 2023). The mentioned distinction explains the ability of some learning platforms to engage participants but fail to retain learned material.

The theory of retrieval learning offers a strong basis for the development of educational technologies based on the idea of multiple knowledge retrievals. Roediger and Karpicke (2006) proved that learning by actively recalling information is more efficient than studying the material through repeated reading. Dunlosky et al. (2013) state that the retrieval practice is one of the most powerful methods that are proven to improve learning efficiency. It was found that quiz-based educational platforms increase students' motivation and contribute to interactions during the lesson (Wang, 2015). However, quizzes do not include the element of assessment into a gamified experience.

Innovations in online learning technologies highlight the significance of analysis in learning environments. According to Banihashem et al. (2024), learning analytics allow generating useful information concerning learner performance, participation, and achievements. The aforementioned issue has special relevance in regard to the implementation of Fun Tac Toe in classroom settings. Interaction records, assessment results, and user feedback generated during the process may contribute to the empirical verification of the application.

Despite evident advancements in the field of gamified and game-based learning, there remains a noticeable gap between complicated serious games and quiz-based solutions. On the one hand, serious games provide great opportunities to engage students but tend to complicate the learning process. On the other hand, quizzes prove inefficient in fostering learner engagement. Fun Tac Toe offers a solution to the problem by incorporating retrieval-based assessment into a simple game mechanism and making the app available on various platforms.

3. System Design and Architecture

The development of Fun Tac Toe takes into account one key factor - the creation of an educational game that will be engaging for users but would not involve them in learning something complicated. In other words, the idea behind it was to create a game that will not involve complex mechanics but will use the classic approach to Tic Tac Toe and introduce educational interaction in the game process.

In its core, the Fun Tac Toe uses retrieval practice as its key learning method. For every mark made by the player, a knowledge-based question should be asked. Correct answer leads to the possibility of putting the mark, while

an incorrect one means that the player loses his/her chance to play at the turn. As a result, any gameplay becomes an educational action in this case. Figure 1 presents the example of interaction between question and gameplay in the game.

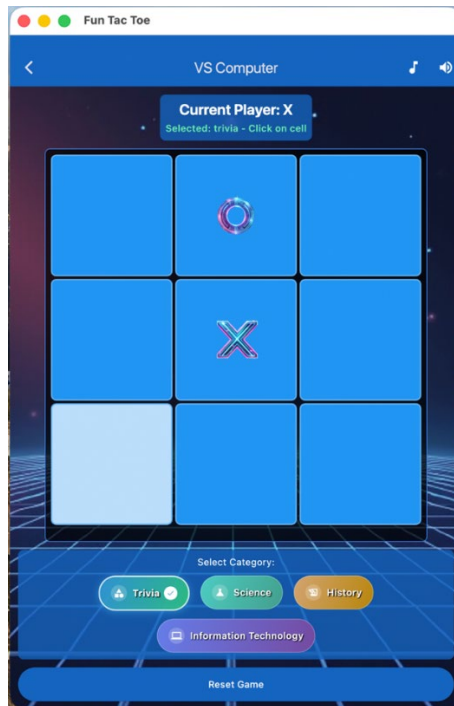


Figure 1: Gameplay interaction in Fun Tac Toe, where players answer knowledge-based questions before placing marks on the board

Accessibility was chosen as one of the key features of Fun Tac Toe, and in order to implement this feature, it was decided to develop the application for different devices with the help of multi-platform approach using Flutter.

For its backend functionality, the framework uses Firebase services to allow user authentication, data synchronization, cloud-based content management, and storage solutions. These features allow the platform to enable either single-player or multiplayer activities and synchronize the game states between connected players. System Architecture is shown in Figure 2 below.

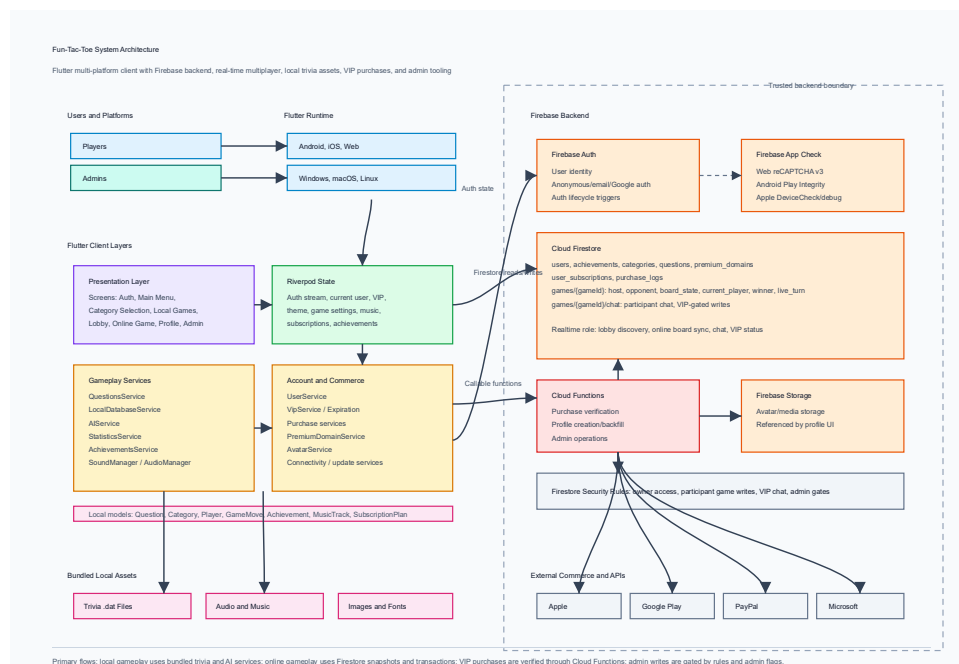


Figure 2: System Architecture for the Fun Tac Toe Educational Platform

In terms of system architecture, the implementation divides the processes of user interaction, gameplay rules, and backend functionality into independent parts. The client application deals with user interface related issues, player interaction with the system, and content rendering. The backend deals with issues like user authentication, handling questions and answers, storing the game states, and managing participant interaction.

The educational content layer is deliberately made scalable. Questions are classified so that the platform can be reused in different educational fields. To put it differently, the gaming process that will be implemented can be used in any education environment that covers different subject matters. In addition, scalability of the architecture allows adding other components. Among them are such components that could be used in classroom settings and further studies of the solution. Because all gaming actions and events can be logged by backend services, the suggested architecture is applicable for empirical research. On the whole, scalability and educational simplicity are the key features of the architecture. Instead of building an elaborate gaming environment, the focus is on developing a functional educational solution.

4. Implementation

The present study identifies the Fun Tac Toe education-based application as a functional cross-platform gaming app that has been built using the technology stack of Flutter and Firebase. The selected technology stack has all the necessary features to help develop cross-platform applications with only one code base.

The Flutter technology enables portability for multiple mobile operating systems, desktops, and web browsers at once. This particular property is particularly relevant considering the goals of the current project, as multi-platform portability makes the proposed game accessible to a wider range of students, regardless of the hardware and software platform used. This feature is clearly observed when entering the game on the web platform. Figure 3 shows the splash screen which contains badges and links to the other platforms where students can download and access the game based on their own personal devices.

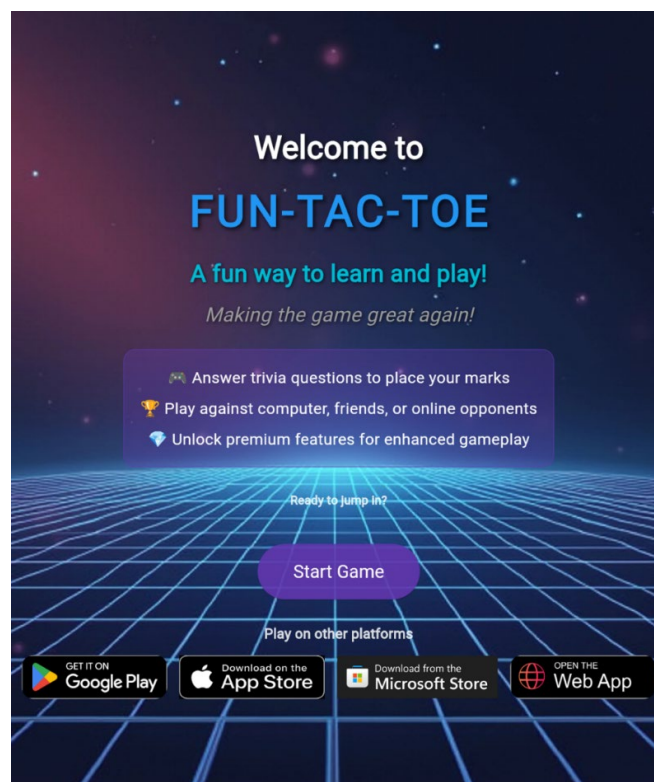


Figure 3: The Splash screen with multi-platform access

Firebase backend cloud services provide the platform required to authenticate and synchronize users, manage educational question banks and gameplay. These services are vital for implementing multiplayer functionality and storing users' progress and information related to the gameplay.

Question engine forms an integral part of the implementation. Questions for games are categorized by topics, which means that the platform can support several educational domains, without changes to the gameplay itself. Figure 4 shows the screen where students can select categories. Categories are grouped by discipline to make

selection of categories access easier and better organized. Currently the game contains over 60 categories, which are clustered into groups such as Arts and Humanities, Children Education, Information Technology, Science and Technology, and Entertainment and Pop Culture. The last group contains categories to make the game more appealing and entertaining, such as movies, food, faction, and music. Some categories contain over 500 questions, which makes the game never boring, and players are hardly to receive the same question twice. Questions are retrieved dynamically during gameplay, which allows students to repeatedly play the game.

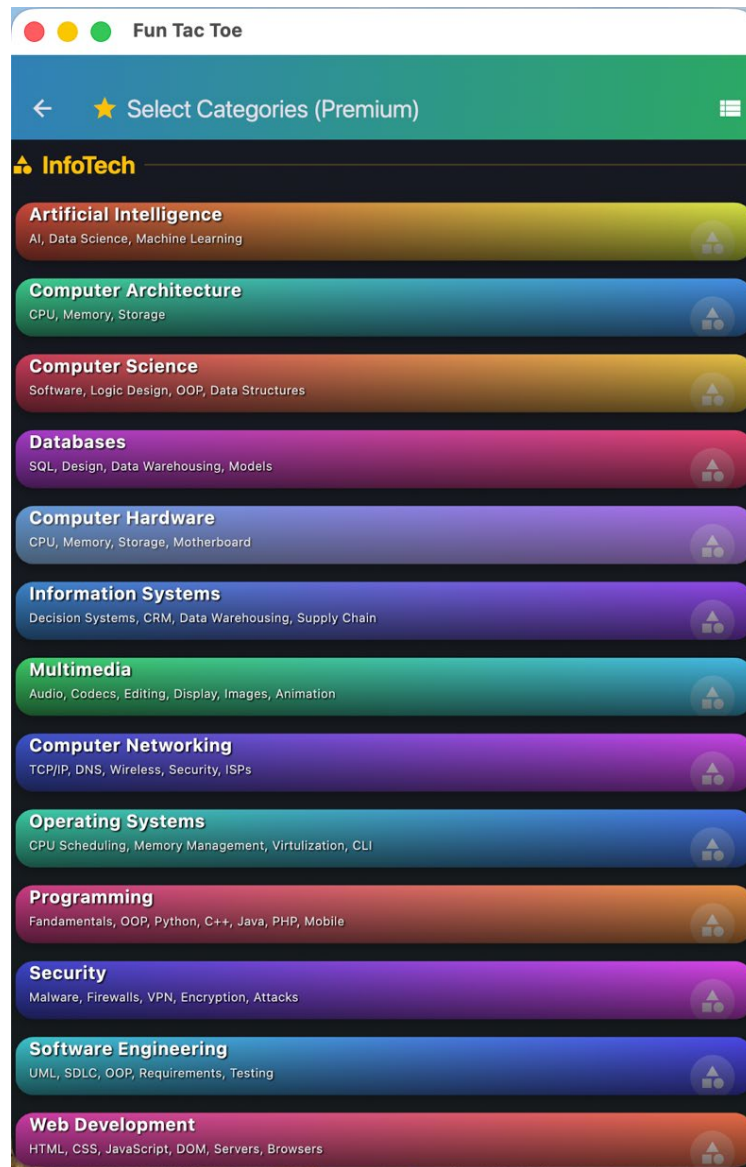


Figure 4: Categories of questions are grouped by discipline

Multiplayer capability is provided through backend synchronization of game states for each player connected to the game server. Consequently, users on different platforms and devices can play the same game at any point in time.

From the architectural perspective, the platform was built in a way that allows introducing new categories of questions, game features, analysis, or educational scenarios without any significant changes to the architecture. This design feature allows implementing research experiments and scaling up to actual classrooms.

In conclusion, it should be noted that modern cross-platform solutions allow implementing lightweight gaming platforms that are highly customizable and accessible for educational purposes.

5. Evaluation Framework and Preliminary Classroom Deployment

To evaluate the educational potential of the Fun Tac Toe platform, an initial classroom deployment was performed alongside with the development of the system. While the objective of this pilot was not supposed to produce definitive evidence of the usefulness of the game, its purpose was to check the feasibility of using Fun Tac Toe in a classroom setting and gather some preliminary educational and usability data for further analysis and large-scale research.

Initially, voluntary students of an undergraduate Data Structures course participated in the study. A special question bank consisting of more than 300 curriculum-aligned test items based on the course textbook was created and embedded into Fun Tac Toe. In the beginning, participants underwent pre-intervention assessment, then used the game to revise their knowledge, and at last, took a post-intervention assessment. Both tests were based on the same intended learning outcomes, meaning that the education provided by Fun Tac Toe corresponded to the course material.

The suggested evaluation framework consists of two aspects – academic performance and user experience. The academic performance aspect is measured through pre- and post-intervention performance, performance relative to the performance in the baseline course, and alignment with the learning outcomes of the course. User experience is about the user engagement, motivation, usability, and interaction with the platform. This is done due to the fact that educational effectiveness of games also relies on engaging students.

The quasi-experimental method is appropriate for evaluating both academic performance and user experience. The student performance information gathered through regular course tests can be taken as a baseline for the study, while post-intervention results, survey feedback, and classroom observation results are additional sources of evidence about the educational value of the system. Moreover, digital assessment tools such as Moodle can provide learning analytics and assessment information as an alternative to traditional instruction.

It can be seen from the preliminary classroom implementation that Fun Tac Toe can be integrated into common teaching practice. Initial results showed that there is a high level of student acceptance along with the positive perception of engagement, usability, and learning assistance. However, since the sample used in the study is relatively small and random, these results should be considered as preliminary.

This framework is flexible enough to be deployed in various subjects, educational levels, and learning environments. The next step of the study is to perform it on a larger sample with the use of learning analytics and controlled classroom study.

6. Discussion

Fun Tac Toe proves that even a classic game can be redesigned as a good educational platform without sacrificing simplicity and accessibility. On the one hand, there are many educational games that use complex narrative or complicated interaction techniques. However, both aspects mentioned above can increase development costs and impose barriers for learners that need an effective way of practicing course material. Therefore, the design principles of Fun Tac Toe include the following points: the platform should keep simplicity of a known game and integrate learning into it.

According to Fun Tac Toe design, players have to solve knowledge-based questions to put their signs to the game board, i.e., knowledge retrieval becomes an important part of the gameplay. Thus, the process of practice is encouraged, but the competitive component is preserved.

One more important feature of the proposed system is its multi-platform architecture. By supporting mobile, desktop, and web environments through a single code base, the platform allows the students to access the game using the devices they already have. This flexibility makes the system easier to use with different educational settings and reduces any technical difficulties to classroom adoption.

The category-based design also makes the platform highly adaptable. Although the initial classroom deployment focused on a Data Structures course, the underlying architecture does not depend on any specific subject. New question banks can be added by the admin without modifying the game mechanics. This allows the same platform to support a wide range of educational disciplines.

The preliminary experience of Fun Tac Toe utilization in the classroom showed that it can be implemented in the current educational process without any problems. The students used the game to revise the information

studied at the lectures. Although the experiment was small-scaled, it produced positive results concerning the usability of the proposed approach.

As with any initial study, this work has some limitations. The classroom deployment included small number of volunteer students and was aimed primarily to check the feasibility of classroom integration rather than to establish definitive evidence of educational effectiveness. Moreover, the questions used during the experiment were setup using Moodle and chosen randomly. Their level of difficulty could vary. Further larger-scale studies with multiple courses, balanced assessment instruments, and longer evaluation periods will be necessary to evaluate learning gains, and the retention of knowledge.

Despite these limitations, the current study shows that a simple and familiar game can become a flexible multi-platform learning tool that can support meaningful educational activities. The combination of simple gameplay, scalable architecture, and curriculum-based question bank provides a great foundation for future research and wider utilization of game-based learning in higher education.

7. Conclusion and Future Work

Fun Tac Toe shows that game-based learning does not necessarily have to incorporate sophisticated game systems and complicated gameplay. By incorporating knowledge-based questions into the familiar game of Tic Tac Toe, the proposed system manages to implement instructional activities within the scope of gameplay itself. Thus, a flexible platform emerges that fosters active recall and engagement of learners.

In addition to developing the working cross-platform application, this project offers a valuable design pattern for educational content integration in game mechanics. As the platform consists of two scalable parts, the question management system and the real-time cloud service, the platform can easily adapt to a variety of educational situations and subjects without changing the gameplay.

The initial classroom testing showed the feasibility of using the Fun Tac Toe system in undergraduate class teaching and even produced encouraging results concerning student acceptance, usability, and classroom integration of the technology. Even though the findings cannot be regarded as empirical yet, they make a good base for future research.

Future research will consist of controlled classroom studies with the use of multiple courses and different student groups. These experiments will help assess the learning effects of the game, knowledge retention, learner engagement, and the correlation between the gameplay dynamics and academic performance by means of assessments, learning analytics, and students' feedback. The further development of the platform with such features as additional game modes, improved learning analytics, and instructors' tools will contribute to its application in higher education institutions.

In conclusion, Fun Tac Toe shows that common game mechanics can be successfully used to create an educational experience for learners. Instead of relying on complex game designs, the proposed approach shows that integrating learning activities into simple, well-known games can provide an effective and scalable foundation for future game-based learning research and practice.

Ethics Declaration: This paper presents the design and implementation of an educational game platform. No human participant data was collected, analyzed, or reported as part of the research presented in this paper; therefore, formal ethical clearance was not required for the current study. Any future classroom-based empirical evaluation will be conducted in accordance with applicable institutional ethical guidelines, including voluntary participation, anonymized data handling, and informed consent where required.

AI Declaration: Artificial intelligence tools were used during the preparation of this manuscript to assist with language refinement and structural editing. All research concepts, system design decisions, technical implementation, academic interpretation, and final manuscript content remain the responsibility of the author.

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