

Collaborative Learning through Gaming: A Case Study of Road Signage Module

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Abstract

The aims of this study were to create a road safety game in a collaborative learning environment based on the EPIC framework and to assess user acceptance of the design. The prototype model has been assessed based on a qualitative approach that involved semi-structured interviews that have been conducted with supervised and unsupervised groups. Participants were 20 children aged 12. The assessment focused on technology acceptance model (TAM) key themes of perceived usefulness, ease of use, user satisfaction, and behavioural intention to explore factors influencing user experiences and willingness to continue engagement. Thematic analysis has been done on the data. Findings indicate that perceived usefulness and ease of use significantly indicate user satisfaction, which, in turn, affects behavioural intentions. Participants valued the model as it enhanced their understanding of road signage and driving ethics, with its interactive format facilitating memory retention and active learning. Although the navigation was intuitive, the scoring system and team-based scoring mechanisms presented usability challenges, highlighting the need for clearer instructions and refinement. The study also suggests that refining the scoring system, improving graphics, and incorporating more complex content could enhance user engagement. This study provides evidence of the feasibility of collaborative learning implementation and how to make it a more impactful tool. It provides a view on how to implement collaborative learning environments in fostering road safety for children. Future work will improve elements highlighted in this study and conduct usability testing with diverse user groups to ensure the application's effectiveness across varied demographics.

Keywords: Acceptance, Collaborative, Game-Based, EPIC, Learning, Road Safety, Road Signage

Introduction

Collaborative learning (CL) is an instructional approach that emphasises interaction and cooperation among learners to attain common academic objectives. It involves individuals

collaborating in groups, exchanging knowledge, and collaboratively addressing challenges to deepen their comprehension of a subject [1]. This method encourages individuals to assume responsibility for their own learning while acknowledging and appreciating the contributions of their peers. It also fosters social learning and the cultivation of problem-solving, critical thinking, and communication skills [2]. Participations where users of differing performance levels working together to enhance their learning outcomes. Definition by Zheng et al. D[3] stated that collaborative learning is a joint effort in which individuals join to acquire knowledge.

Road safety primarily aims to enhance knowledge and encourage safe practices among road users, and it has been integrated into school curricula through co-curricular courses. Studies demonstrate that effectively coordinated interactions with suitable road signage promote understanding, resulting in improved traffic flow, increased road safety, and a reduction in accidents [4]. Interventions that account for environmental factors, including adequate signage and road conditions, are essential for pedestrian safety and minimising fatalities [5]. Consequently, incorporating collaborative gaming principles into road safety instruction is expected to foster engaging learning in an interactive manner. Multiplayer games enable users to collaboratively address road safety concerns, enhancing their comprehension of road signage while promoting teamwork and cooperation.

However, the advantages of educational games in improving knowledge and skills are well-documented, there is a significant deficiency in research about collaborative learning in road safety education, especially for school-aged children. A framework, which is one of the game design frameworks, which emphasises engagement, purpose, inspiration, and challenge (EPIC), offers a basis for creating games that enhance engagement and facilitate meaningful as well as purpose-oriented collaboration. Thus, this study aims to develop a prototype collaborative learning application within a road safety context. Implement the EPIC framework and evaluate user acceptance of game design using technology acceptance model (TAM). The significance is to find evidence that integrating collaborative learning methodologies and technologies into road safety education is feasible. This paper comprises the following structure: Section 1 provides the study's background, while Section 2 explores the literature on road safety signage awareness games. Section 3 presents the methodology and Section 4 presents the results. Followed with Section 5 that presents the discussions. Finally, Section 6 closes by concluding the study's contributions and describing future work for game enhancement.

Review of Literature

CL is a user-centered approach that promotes active engagement, knowledge sharing, and cooperative problem-solving among learners. Collaborative learning environments, frequently enhanced by computer-supported technologies and promote efficient knowledge exchange and collective problem-solving [6]. It is also known as computer-supported collaborative learning (CSCL) which is a pedagogical approach where learning occurs through social interaction using computers or the internet [7]. This method emphasizes the sharing and construction of knowledge among participants, leveraging technology as the primary means of communication or as a common resource. It includes elements like collective objectives, constructive interdependence, and personal responsibility to foster collaborative interactions. In addition, it facilitates dynamic convergence of participants pursuing

competing objectives, which improves teaching and learning results in online environments [8].

In the context of road safety CL application, it requires implementation of game elements into non-gaming environments [9]. Gamification seeks to guide users towards desired behaviors by establishing a game-like experience [10]. Basic lessons like road signage for left turn signs, markedly improve safety among children. This indicates that introducing road signage is essential for educating children about road safety. Furthermore, integrating road safety education into school curricula such as in the serious games-based module would be able to foster safe behaviours among kids [11]. To assess the acceptance of the CL application, it must be evaluated based on user satisfaction and learning outcomes among children [12]. To understand the concept of CL, Table 1 outlines its fundamental elements.

Table 1

Elements in Collaborative Learning

Author	Elements	Descriptions
Veldkamp et al., 2022 [13]	Positive Interdependence	Encouraging learners to work together towards shared goals, where everyone's success is linked to the success of the group.
	Face-to-Face Interaction	Promoting direct communication and engagement among learners to facilitate meaningful discussions and collaboration.
	Individual Accountability	Holding each learner responsible for their contributions and ensuring that all members actively participate in the collaborative process.
	Social Skills	Developing interpersonal skills such as communication, cooperation, and conflict resolution to enhance group dynamics and interactions.
	Group Processing	Reflecting on group activities, evaluating progress, and adjusting strategies to improve collaborative learning outcomes.
Keith et al., 2019 [14]	Group Roles	Assigning specific roles within the group to regulate activities, facilitate coordination, and enhance learning experiences, especially in Computer-Supported Collaborative Learning (CSCL) environments.
Zhao & Cao, 2023 [15]	Self-Regulated Learning (SRL)	Encouraging learners to take control of their learning process, set goals, monitor progress, and adapt strategies to achieve optimal learning outcomes.
Wang, 2021 [16]	Social Support	Aid, encouragement, and feedback to group members to create a supportive learning environment and foster collaboration.
Sousa et al., 2019 [17]	Scaffolding	Offering guidance, structure, and support to learners as they engage in collaborative activities to promote learning and skill development.
	Mutual Support	Encouraging learners to assist and learn from each other, fostering a sense of community and shared responsibility for learning.

CL elements in Table 1 can be intergrated in the EPIC framework [18]. The framework outlines four key elements in collaborative learning: Engagement refers to students' attention, motivation, and participation; Participation involves their active involvement in the learning process; Interaction emphasizes the exchange of ideas between students, instructors, and peers; and Collaboration focuses on joint efforts and teamwork to achieve learning goals.

Implementation of CL in previous research are various. A study implemented collaboration training in healthcare through a multiuser game where it focusses on key cooperation traits[18]. Findings from the study stated that incorporating collaborative elements into gaming environments enhance cooperation skills. Similarly, Law et al. [20] investigated gamification's role in improving cooperative skills in an online tournament setting. Findings of this study also provide valuable insights into how gamification features facilitate collaborative learning and team development. Riivari et al. [21] also explored the impact of computer game-based cooperative training on performance and collaborative learning, highlighting its potential in enhancing teamwork skills. Wang and Huang [16] extended this line of study by emphasizing the importance of game design in creating environments conducive to collaborative learning through serious games. Whereas Carolin and Lintangari [2] demonstrated that game-based collaborative methods could enhance learning outcomes and at the same time cultivates skills of problem-solving and critical thinking. In the context of road safety, Johari et al. [22] found that interactive road safety games effectively teach children safety knowledge. In addition, their study emphasizes the importance of creating engaging and educational games aligned with the EPIC framework's. Similarly, resembling real-world scenarios could improve children's learning outcomes[23].

As mentioned previously, TAM can assess user acceptance which it comprises of major construts of perceived usefulness (PU) , perceived ease of use (PEOU) and user satisfaction (US) [24]. TAM helps to understand the rationale behind users' acceptance or rejection of technology and to anticipate the adoption of new technologies. Figure 1 depicts TAM adaptation from conceptual model by Legramante et al. [25]. PEOU refers to the degree to which a person believes that using the apps would be effortless, and the easier users found it to navigate and understand, the more satisfied they became. PEOU built a sense of confidence and positively impacted the US. PU is the degree to which a person believes that using a particular application is beneficial. If users find the apps helpful, it further enhances their satisfaction. At this point, both PEOU and PU combined to contribute to satisfaction. Consequently, US influenced users' behavioral intention to use (BI) the apps. When users felt satisfied, they were more likely to adopt and continue using the system. In this study, TAM theoretical assumptions based on study by Legramante et al. [25] serve as foundational elements that guide the study's design, methodology, and interpretation of findings. Figure 1 illustrates the concept of the assumptions.

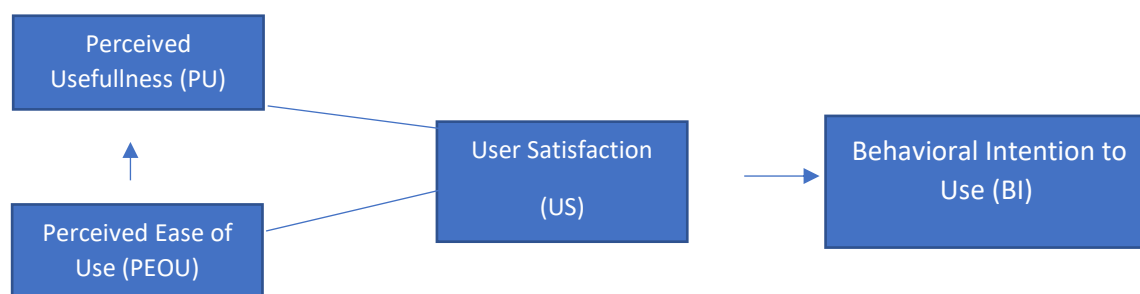


Figure 1. TAM theoretical assumptions (Adapted from Legramante et al.[25])

Methodology

This study comprised of four main stages: user requirements, design, implementation, and user acceptance testing. The user requirements phase involved conducting interviews with school road safety instructors and analyzing relevant modules. This was followed by the design phase, during which a storyboard was created to visualize the game's flow, object placement, and scoring mechanism. To ensure balanced scoring, simulations and analyses of scoring probabilities were conducted, allowing for multiple replay experiences during development. Next, the user acceptance assessment was then conducted. Since the game is specifically tailored for children in suburban areas and the experiment was implemented as part of a corporate social responsibility (CSR) program with primary school children. Figure 2 below illustrates the study flow.

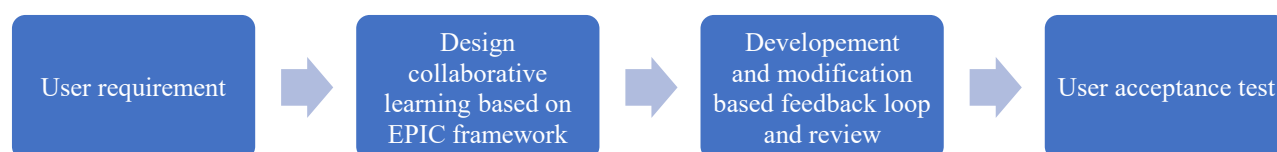


Figure 2. Study Flow

Elements identified in Table 1 (in Section 2) were integrate into the EPIC framework game design as to enhance the alignment between educational goals and game mechanics. The following, Table 2 describe the implementation of collaborative elements into the CL apps design.

Table 2

Design implementation in the CL apps

EPIC Criteria	CL elements	Design implementation
Engagement	Face-to-Face Interaction: Promotes active, real-time participation, fostering direct communication and teamwork, engaging learners through interaction. Group Roles: Involves users in various roles, contributing to group tasks, which increases personal investment and engagement in the game. Social Skills: Encourages interaction and cooperation within teams, making the experience more engaging by focusing on effective communication and teamwork.	Face-to-Face Interaction: Users take turns providing answers and work together as a team. Division of Roles: Each user is assigned a specific role or task that complements the others. Synchronized Actions in sequences: Users must synchronize their actions to progress in the game. This involves real-time communication and decision-making where each user's move is contingent on the actions of the others.
Purpose	Positive Interdependence: Emphasizes shared goals, where each member's success is linked to the group's success, giving clear purpose to collaborative efforts. Mutual Support: Aligns with the purpose by reinforcing the idea that collaboration and cooperation are key to achieving the game's objectives. Self-Regulated Learning (SRL): Aligns individual goal setting and reflection on progress, giving purpose to personal efforts in a collaborative environment.	Collective Scoring: The scoring mechanism fosters interdependence among users. During the game, users support one another by providing tips and hints to help identify the correct answers, but the final decision is made by the user whose turn is active. Points are awarded based on the team's collective performance rather than individual achievements. This fosters a sense of shared responsibility and encourages users to support each other.
Inspiration	Social Support: Motivates users by creating a collaborative atmosphere where learners feel encouraged and supported, inspiring deeper participation and growth. Scaffolding: Offers guidance at critical moments to inspire learners to achieve more complex tasks and build confidence in their abilities.	Open space and think-aloud practices are highly encouraged, fostering a collaborative atmosphere that motivates users and allows learners to feel supported and encouraged. Problem-Solving and Strategy: User emphasizes collaborative problem-solving and strategic planning. They discuss and plan their moves, anticipate challenges, and devise strategies to overcome obstacles.
Challenge	Individual Accountability: Holds each user responsible for their contributions, challenging them to perform and contribute to the team's success. Group Processing: Encourages reflection on group performance, promoting critical thinking about collaborative strategies and challenges faced.	Scoring is based on both individual and team contributions, challenging them to enhance their performance for the team's success. Feedback and Adjustment: The game can provide real-time feedback on the team's performance, allowing users to adjust their strategies and improve coordination.

In the game play, the user assigned to identify the signage and successfully navigation without incidents earns the team points. The concept of "*Interlace user*" is implemented where users work together interchangeably in to achieve a common goal, such as collecting score points. Figure 3 illustrates the game play scenario and Table 3 illustrates some of the screen shots.

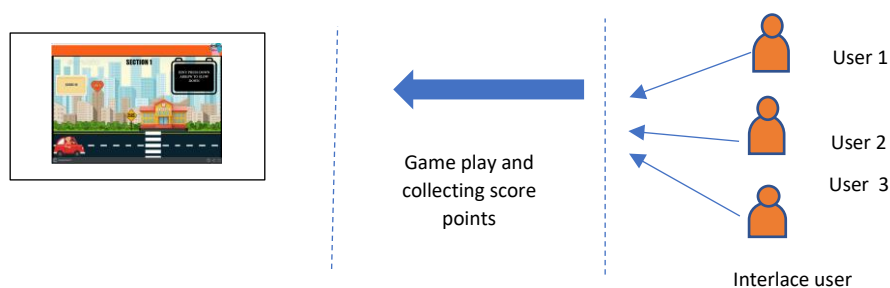


Figure 3. Game play scenario

Table 3

Example of the screen shots

Module Description		
 Module 1: Navigate the car when bumped into the stop signage	 Module 2: Navigate the car when bumped the no right turn signage	 Module 3: Navigate the car when bumped into the no entry signage

The sampling frame included children aged 11 to 12 who participated in the road safety CSR program conducted at their school. Respondents were drawn from participants who engaged in gameplay sessions during the program. Out of 150 participants who attended the 2-day event, 20 children were selected based on their observed responsive behavior, willingness to participate, and demonstrated ability to think aloud during activities. A purposive sampling method was adopted, as the selection focused on specific characteristics aligned with the study's goals. This approach supports the research objective of evaluating children's acceptance of road safety collaborative learning through gameplay, ensuring the selected participants provided meaningful insights. The chosen respondents offered sufficient data saturation to effectively describe and explain the acceptance of the collaborative learning game within this targeted context.

Results

The results are presented in Table 5, which summarizes the outcomes from the thematic analysis and Figure 4 illustrate the sub themes of each of the themes.

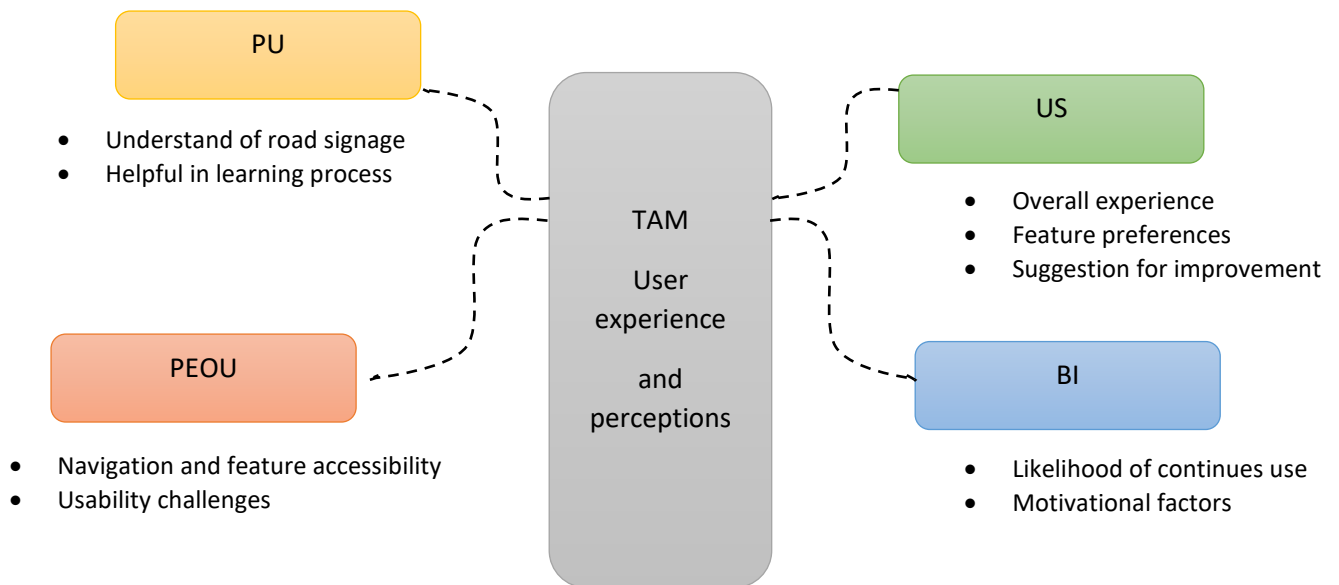


Figure 4. Illustrate the theme and sub themes

Table 5

Outcome from Thematic Analysis

Theme	Sub-Theme
Theme 1 Perceived usefulness	Sub-theme 1.1: Understanding of Driving Ethics This application significantly improves users' understanding of driving ethics. Users report that the application not only provides new knowledge but also increases their awareness of road signage and driving protocols. Many users mention that, while they have often seen various signs while riding their bikes or traveling in a parent's car, they have previously paid little attention to these signs. The application enables users to grasp the meaning and importance of each sign more clearly, enhancing their practical understanding of driving ethics and safety. This shift from casual observation to informed understanding helps users feel more confident and attentive on the road, ultimately fostering safer driving habits.
	Sub-theme 1.2: Helpfulness in Learning Process The application is helpful in facilitating the learning process for user. Participating in the game allows users to move from a state of limited knowledge to a clear understanding of road safety and driving ethics. The interactive nature of the game aids memory retention, making it easier for users to remember what they have learned. Users often recall specific concepts taught by trainers during pre-game talks, reinforcing these lessons as they engage in the game with friends. This collaborative, hands-on approach strengthens their understanding and helps them apply the knowledge more naturally, especially when interacting with others in a fun, supportive environment.
Theme 2 Perceived ease of use	Sub-theme 2.1: Navigation and Feature Accessibility Users find the application easy to navigate and its features accessible. Facilitators provided clear instructions on using the app, helping users become familiar with its layout and functions before they began playing. Once they started using it, users found the app to be straightforward and user-friendly. The design is intuitive, with all features presented in a logical flow, so users rarely need to ask for guidance on what to do next. The game employs common symbols that are easily recognizable, making it accessible even for first-time users. This simplicity allows users to focus on learning

	and engaging with the game, rather than struggling with complex navigation or unfamiliar icons. Sub-theme 2.2: Usability Challenges Certain aspects of the tool may be challenging to understand or use. While the animated quiz on identifying signage isn't difficult if users pay attention during the pre-game talk, some users struggle with understanding how scoring works. For example, users found it unclear that if one team member answers a quiz question incorrectly, it results in a points deduction for the entire team. This has led to some confusion, as users were not fully aware that their success relied on collaboration and providing collective support to help teammates answer correctly. The concept of teamwork, where each member's understanding directly impacts the group's score, was not entirely understood by all users, highlighting an area where clearer instructions on collaborative gameplay could enhance the experience. <i>"We didn't realize that if one of our team members answered the quiz incorrectly, the whole team's points would be deducted. Maybe we didn't fully understand what collaboration meant—we needed to really help our teammates provide the correct answers."</i>
Theme 3 User satisfaction	Sub-theme 3.1: Overall Experience Users have a positive overall experience with the application. The app provided an enjoyable and engaging experience for users, who found the gameplay both fun and enriching. <i>"It was fun, and we enjoyed the togetherness in playing games,"</i> one respondent shared, reflecting on the sense of camaraderie the game fostered. Users appreciated helping each other with quiz questions, creating a supportive environment where everyone contributed to finding the correct answers. Although some felt the time for each quiz was limited, this added to the excitement, especially as they watched their opponents react and make noises, adding an element of friendly competition. The experience was even more rewarding when teammates offered help, reinforcing a strong sense of teamwork and mutual support throughout the game. Sub-theme 3.2: Feature Preferences Users particularly enjoy specific features of the application. One of the standout features is the sound effect that plays when users earn points for a correct answer. Users find the audio both funny and motivating, enhancing their overall enjoyment of the game. <i>"Every time we score, the sound just makes us laugh and feel good about our progress,"</i> one respondent noted. However, some users suggested that the cartoon characters could be improved with higher-quality graphics to elevate the visual experience further. Despite this, the excitement surrounding the scoring system is undeniable; users are highly motivated by the points calculation and the awards they receive, which fuel their desire to earn even more marks. This combination of engaging sound effects and a rewarding scoring system creates an exhilarating atmosphere that keeps users actively participating and striving for higher achievements. Sub-theme 3.3: Suggestions for Improvement Users believe there are areas for improvement to increase satisfaction. Many users expressed that enhancing the graphics would significantly improve their experience. They feel that high-quality visuals would make the game more engaging and immersive. Additionally, they noted that it would be simpler and more enjoyable if each user could use their own device, rather than sharing a single laptop among team members. This change could enhance individual participation while still fostering a sense of togetherness among users.

	Furthermore, users suggested incorporating more challenging and difficult signage into the game. They believe that including a wider variety of signs would not only test their knowledge more rigorously but also make the gameplay more stimulating and educational. By addressing these areas for improvement, the application could better meet user expectations and enhance overall satisfaction.
Theme 4 Behavioral intention to use	Sub-theme 4.1: Likelihood of Continued Use Users are likely to use the application regularly to enhance their driving ethics. Many users expressed a strong commitment to participating in the program again next year, highlighting their enthusiasm for continuous learning. "<i>We hope to represent our school if there's a road safety signage competition,</i>" one respondent mentioned, reflecting their desire to showcase the knowledge and skills they've gained from the application. This eagerness to compete emphasizes their belief in the value of the program and the application in improving their understanding of road safety. Additionally, users voiced a wish for the game to be made available in their computer lab. They believe having access to the game on school computers would allow them to practice more frequently, reinforcing their learning and keeping the concepts fresh in their minds. This desire for regular engagement with the application indicates a proactive attitude towards enhancing their driving ethics, demonstrating that users not only find the application beneficial but are also motivated to integrate it into their educational environment. Sub-theme 4.2: Motivational Factors Certain factors would encourage users to use the tool more frequently. Users expressed optimism that improvements to the game in future programs would significantly enhance their engagement. They specifically mentioned a desire for better graphics, noting that higher-quality visuals would make the gaming experience more captivating and enjoyable. Additionally, users hope to see more exciting sound effects incorporated into the game, as well as the addition of an audible commentator's voice to provide real-time feedback and commentary during gameplay. Moreover, they suggested that when points are awarded, it would be fun to have a character pop up to celebrate achievements, adding a playful element to the experience. Users also expressed interest in incorporating surprise features, such as selecting the best user and team, to introduce an element of competition and recognition. These enhancements would not only make the game more engaging but also foster a lively atmosphere that encourages users to return and participate regularly, making the learning process both fun and rewarding.

Discussion

Theme 1, perceived usefulness, highlights how users view the application's educational impact. This theme is divided into two sub-themes: understanding of road signage and helpfulness in learning process. Users reported that the application significantly enhanced their understanding of road signage, helping them shift from casually observing signs to actively recognizing and interpreting them with greater awareness of road safety. Additionally, the application supports learning by facilitating memory retention and simplifying the grasp of driving ethics concepts, which strengthens users' foundational knowledge and contributes directly to their satisfaction. Theme 2, ease of use, focuses on the

usability of the application. This theme covers navigation and feature accessibility and scoring points usability challenges. Users found the application intuitive and easy to navigate, allowing them to engage with minimal support and concentrate on learning rather than the interface. However, some users encountered challenges with the scoring system, particularly around understanding how team-based scoring and collaboration affect their overall success. While the application is generally accessible, these usability challenges suggest that certain elements might benefit from clearer instructions or a redesign to reduce confusion.

Theme 3, user satisfaction, is influenced by both perceived usefulness and ease of use, making it central to the overall model. User satisfaction is broken down into three sub-themes which are positive overall experience, feature reference, and suggestions for improvement. Although users favour with experience, but they also proposed modifications including improved visuals, personalised device access, and more intricate road signs, suggesting that specific adjustments could further elevate satisfaction. Diagram in Figure 5 maps out user feedback across four main themes. Each theme includes sub-themes that highlight factors influencing users' experiences and intentions to keep using the application.

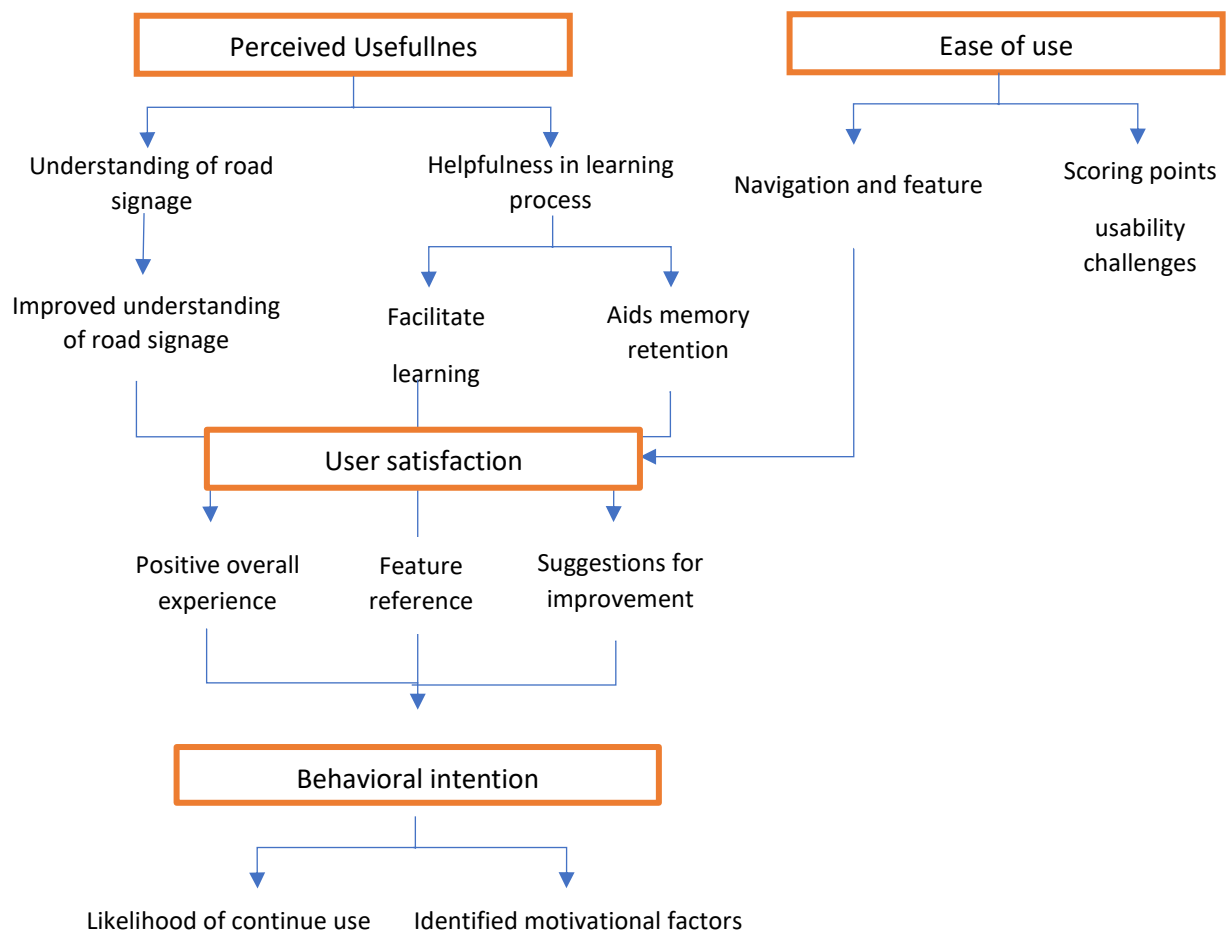


Figure 5. User feedback across four main themes

Theme 4, behavioural intention, reflects users' inclination to persist in utilising the application. This intention is motivated by satisfaction and perceived utility, with users indicating interest in next sessions and competitions. It is recognised that motivational aspects comprise prospective enhancements such as better graphics representations,

interactive sound effects, interesting character animations, and unexpected pop-up features to enhance player enjoyment and reward. Users appreciate the application's educational advantages and generally they find it as user-friendly. These observations indicate that the apps are beneficial in fostering driving ethics and road safety, although there is potential for enhancements that could bolster user retention and engagement.

Comparison with Previous Empirical Evidence

The key relationships between themes and their comparison with previous empirical evidence are summarized in Table 7 below.

Table 7

Key relationships between themes and comparison with previous empirical evidence

Theme relationship	Comparison with previous empirical
Theme 1 Perceived usefulness and user satisfaction	The educational value of the application strengthens users' foundational knowledge and positively influences their overall satisfaction. Amalia and Fahrudi [26] highlight a significant positive relationship between perceived usefulness and user satisfaction, reinforcing findings from other research that emphasizes the importance of perceived usefulness in enhancing user satisfaction in mandatory settings. This model is further supported by Uwamungu[27], who discusses how user satisfaction is influenced by the perceived impact of the system on individual work performance, indicating that perceived usefulness contributes to user satisfaction through enhanced system performance.
Theme 2 Ease of use and user satisfaction	Wicaksono et al. [28] support this finding by arguing that enhancing an application's usability directly leads to increased user satisfaction, thereby reinforcing the notion that user-friendly systems are more likely to meet user needs. Oktal et al. [29] assert that users' views of ease of use substantially influence their satisfaction levels, confirming the extensive literature that highlights the significance of usability in system design. Wuryandari [30] also stated that this paradigm asserts that user acceptance and satisfaction are significantly influenced by the simplicity of use.
Theme 3 User satisfaction as a central factor	The relationship between perceived utility and perceived ease of use is essential for comprehending user satisfaction in educational apps. Akbar and Nurmahdi [31] discovered that perceived utility and perceived ease of use significantly enhance user happiness, demonstrating that these factors collaboratively improve the entire user experience. Zhou et al. [32] further corroborate that perceived ease of use directly impacts perceived usefulness, therefore influencing user happiness. Furthermore, Liu et al. [33] conducted a study that highlights how perceived usefulness and simplicity of use affect user satisfaction with mobile learning applications, indicating that these elements are crucial for enhancing user engagement and learning outcomes.
Theme 4 Behavioral intention driven by satisfaction and usefulness	Users' satisfaction and perceived usefulness influence the likelihood of continuing to use the application. Positive experiences and motivational factors, including enhanced graphics, auditory effects, and additional features, boost users' intentions to interact with the application in subsequent sessions, emphasizing the significance of augmenting both enjoyment and perceived utility. Utami [34] found that user pleasure, through perceived ease of use, positively influences behavioral intentions. This indicates that both perceived utility and usability enhance user happiness, thereby influencing behavioral intentions. Eveleth & Stone [35] analyzed users' perceptions of mobile applications and found that contentment significantly predicts users' intentions to continue using an app, particularly when perceived utility increases. Their findings suggest that users who perceive an app as beneficial and gratifying are more likely to wish to persist in its usage.

Conclusion

The study demonstrates the feasibility of implementing collaborative learning models while offering insights into optimising interactive learning environments to encourage ethical driving behaviour. User acceptance of a collaborative learning model designed using the EPIC framework that aims to enhance understanding of driving ethics and road safety through a game-based application have been conducted and presented. Overall results from TAM assessment indicate that perceived usefulness and ease of use are key predictors of user satisfaction, which strongly influence behavioral intentions. Users generally agree that the application supports their understanding of traffic signage and driving ethics, with its interactive structure promoting memory retention and active learning. However, issues with the scoring system, particularly team-based scoring, were noted, suggesting a need for clearer instructions to reduce confusion. Future enhancements should prioritize thorough usability assessment to refine scoring systems and collaboration features. Additionally, improvements such as enhanced graphics, individual device access, and the inclusion of more complex road signage content could significantly boost user engagement and satisfaction. In that vein, conducting usability testing with diverse user groups will help ensure the application's effectiveness across varied demographics.

Contribution to Theory and Context

This study makes both theoretical and contextual contributions by integrating collaborative learning, gamification, and the TAM within road safety education. Theoretically, it extends collaborative learning principles by incorporating the EPIC framework into a game-based learning model. This integration aligns with Computer-Supported Collaborative Learning (CSCL) theories, emphasizing the role of digital environments in fostering cooperation and engagement. Additionally, by assessing using TAM constructs within a road safety learning context, this research provides insights into how usability and engagement enhance learning effectiveness. From a design perspective, the study identifies key challenges, such as team-based scoring confusion and navigation difficulties, which impact user experience. To address these issues, it suggests enhancing instructions, refining scoring mechanisms, and improving graphics to boost user engagement and learning outcomes. Contextually, this study presents a practical model for integrating game-based collaborative learning into school curricula. It contributes to road safety education theory by demonstrating that experiential and interactive learning methods effectively enhance children's understanding of traffic signage and driving ethics. Furthermore, it provides valuable insights for policymakers in developing digital intervention strategies for road safety education among school-aged children.

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