Game-Based Applications for Traffic Education: A Systematic Literature Review

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Abstrak. *Meningkatnya jumlah insiden lalu lintas di kalangan remaja menunjukkan perlunya metode pendidikan lalu lintas yang lebih menarik. Tinjauan literatur sistematis ini mengkaji karakteristik, tujuan pembelajaran, elemen permainan, dan metode evaluasi pada game edukasi lalu lintas. Dengan menggunakan kerangka Kitchenham, pencarian terstruktur pada tiga basis data menghasilkan 10 studi utama dari 834 artikel. Temuan menunjukkan bahwa sebagian besar game menargetkan anak-anak dan disampaikan melalui platform mobile atau virtual reality. Tujuan pembelajarannya terutama berfokus pada penguatan pengetahuan lalu lintas dan perubahan perilaku. Elemen game yang umum digunakan meliputi poin, tujuan, dan level. Metode evaluasi sebagian besar menilai performa dan kesenangan pengguna, dengan hasil yang umumnya positif. Tinjauan ini juga mengidentifikasi adanya kesenjangan studi yang menargetkan remaja. Penelitian selanjutnya perlu mengembangkan game yang imersif dan berfokus pada perilaku, dengan indikator yang jelas untuk mengukur hasil pembelajaran dan perubahan perilaku.*
Kata kunci: *Keselamatan Jalan, Pembelajaran Berbasis Game, Pendidikan Lalu Lintas, Perubahan Perilaku, Serious Games*

Abstract. *The rising number of traffic-related incidents among youth shows the need for more engaging traffic education methods. This systematic literature review examines the characteristics, learning objectives, game elements, and evaluation methods of traffic education games. Using Kitchenham's framework, a structured search across three databases identified 10 primary studies from 834 articles. The findings show that most games target children and are delivered through mobile or virtual reality platforms. Their learning objectives primarily focus on reinforcing traffic knowledge and promoting behavioral change. Common game elements include points, objectives, and levels. Evaluation methods mostly assess performance and enjoyment, with generally positive results. This review also identifies a gap in studies targeting teenage learners. Future research can develop immersive and behavior-focused games with clear indicators to measure learning outcomes and behavioral change.*
Keywords: *Behavioral Change, Game-based Learning, Road Safety, Serious Games, Traffic Education*

1. Introduction

Traffic safety remains a critical issue, as road traffic accidents are among the major causes of injury and death among children and adolescents. The World Health Organization reports that traffic incidents are the third leading cause of death among children globally [1]. This situation highlights the need for traffic education that not only delivers knowledge but also promotes safe behavior and road awareness. However, traditional teaching methods, which often rely on static materials and lectures, tend to be passive and less effective in sustaining learner engagement and long-term knowledge retention [2].

Game-based learning and serious games have emerged as promising approaches for road safety education, particularly as alternatives to traditional, knowledge-based programs [3], [4]. By providing interactive, immersive, and risk-free environments, virtual reality (VR)- and game-based systems allow children and adolescents to repeatedly experience traffic situations, practice road crossing, recognize hazards, and apply traffic rules without real-world danger [5], [6]. These applications support active learning, cognitive engagement, traffic rule comprehension, road awareness, and hazard perception, while also encouraging behavioral intentions toward safer road

use [3], [4], [6], [7]. Therefore, their experiential nature makes them valuable not only as entertainment tools, but also as pedagogical media for traffic and road safety education.

As game-based and VR-supported traffic education applications continue to develop, research in this area has become increasingly diverse in terms of target users, platforms, learning objectives, game elements, and evaluation methods. Studies such as those by [8] and [9] highlight how game-based and VR-driven learning systems can be designed to meet educational goals while catering to diverse age groups. However, existing studies are still scattered and often focus on individual applications rather than providing a broader understanding of the field. A systematic literature review is therefore needed to synthesize current evidence, identify common design and evaluation patterns, and reveal research gaps related to the effectiveness of game-based applications in improving traffic knowledge, awareness, and safe road behavior.

This study presents a systematic literature review of traffic-related educational games. It examines their characteristics, objectives, game design components, target users, and evaluation metrics. The novelty of this study lies in its focused synthesis of game-based applications for learning traffic rules and road-safety behavior, an area that has received limited systematic attention. This study contributes by mapping current research trends, identifying key design and evaluation patterns, and highlighting gaps for future studies, particularly the need for immersive and behavior-focused traffic education games for teenage learners.

2. Related Work

In this systematic literature review, the term game-based applications is used broadly to refer to learning applications that use games or game elements to support educational goals. These applications usually include digital games but may also include board or card games intentionally designed to teach specific knowledge or skills. They are available across various platforms, such as web-based or e-learning systems, mobile applications, 3D/VR simulations, and serious games designed for classroom learning or professional training [10], [11], [12]. Many popular platforms also integrate gamification elements, such as points, badges, levels, leaderboards, and challenges, into learning management systems or online applications [13], [14]. In general, game-based learning across different educational levels, from early childhood education, primary and secondary education, to higher education and vocational training, has been shown to improve learning outcomes, understanding of complex concepts, problem-solving skills, critical thinking, and the application of knowledge to real-world situations [10], [15]. Teachers also perceive educational digital games as useful for increasing students' motivation, active engagement, collaboration, and digital competence [16]. A meta-analysis in early childhood education further shows moderate to large effects on cognitive, social, and emotional development, as well as motivation and engagement, when game-based learning is used appropriately [17].

Traffic education refers to education on road safety, including road rules, traffic signs, and safe behavior as pedestrians, cyclists, passengers, and future drivers. This program usually begins in preschool and primary school because children are a vulnerable group, and many accidents occur when they travel to and from school [18], [19]. Effective traffic education considers children's cognitive development stages and uses play-based or practical approaches, such as simulators, mini traffic cities, and virtual reality, to help children practice road-crossing skills, recognize traffic signs, and perceive hazards without real-world risk [3]. Studies across various countries show that school-based road safety programs can improve risk awareness and helmet and seat belt use. However, behavioral changes are often small or short-term, so repeated "top-up" interventions are needed before and during the pre-driver age [20], [21]. Safe driving education at the junior high school level has been shown to improve understanding and prepare teenagers scientifically and mentally before they reach the legal driving age. It can also help develop more responsible driver behavior in the future [19]

A systematic literature review is important because it provides a structured way to identify, evaluate, and synthesize existing studies on a specific topic. In this study, the SLR approach is used to map current evidence on game-based applications for traffic education and to identify research trends, design patterns, evaluation methods, and remaining gaps. The review

follows Kitchenham's protocol [22], which consists of three main stages: planning, conducting, and reporting the review. The planning stage defines research questions, search strategy, databases, and inclusion and exclusion criteria. The conducting stage involves searching, screening, selecting studies, and extracting relevant data. The reporting stage presents and synthesizes the findings in response to the research questions. This protocol helps ensure that the review process is transparent, systematic, and replicable.

3. Methodology

Our systematic literature review followed the guidelines proposed by [22]. This section describes each stage of the research process, including the formulation of research questions, the search strategy, the selected databases, and the procedures used for data extraction and analysis.

3.1 Research Questions

The purpose of this systematic literature review is to analyze the characteristics, educational goals, game elements, and evaluation methods of game-based applications for traffic education. This review aims to synthesize current research trends and identify design and evaluation gaps that can support the future development of more effective traffic education games. Table 1 shows the research question for this systematic literature review.

Table 1. Research Questions

ID	Research Question
RQ1	What are the characteristics of existing game-based applications for traffic education?
RQ2	What educational goals and traffic-related content are addressed in game-based applications for traffic education?
RQ3	What game elements are used in game-based applications to support traffic education goals?
RQ4	What evaluation metrics and outcomes are used to assess game-based applications for traffic education?

The first research question (RQ1) examines the main characteristics of traffic education games in the selected primary studies. The second question (RQ2) identifies the educational goals of these games and the traffic-related content they present. The third question (RQ3) explores the game elements used to support learning and reinforce the intended goals. The fourth question (RQ4) investigates the evaluation metrics and outcomes used to assess game-based applications for traffic education, including learning performance, enjoyment, replay intention, and application usability.

3.2. Search Strategy

The search strategy began by defining two main keywords: "traffic behaviour" and "game". These keywords were expanded using synonyms, spelling variations, and related terms. The term "traffic behaviour" was expanded to include "traffic behavior", "traffic regulation", "traffic safety", "traffic awareness", and "traffic education". The term "game" was expanded to include "serious game", "video game", "game-based learning", "game based learning", "GBL", "educational game", and "gamification". These terms were combined using Boolean operators. The operator "OR" was used to connect similar terms, while "AND" was used to combine the two main concepts. The main search string was:

("traffic behavior" OR "traffic behaviour" OR "traffic regulation" OR "traffic safety" OR "traffic awareness" OR "traffic education") AND ("serious game" OR "game-based learning" OR "game based learning" OR "GBL" OR "educational game" OR "game" OR "video game" OR "gamification")

Several databases were tested to assess their suitability for this review. This process also helped identify additional related terms for the search string. Based on the test results, three databases were selected: IEEE Xplore, Scopus, and ScienceDirect. A simplified search string was used for ScienceDirect because the database limits the number of Boolean operators in one query.

The final search was conducted in the three selected databases using the defined search string. The search was limited to the title, keywords, and abstract to capture studies that were

directly relevant to the topic. The publication period was set from 2021 to 2025 to obtain recent studies. Some adjustments were made for each database because each database has different search features and limitations. The specific search scope and query string for each database are presented in Table 2.

Table 2. Query String for Each Database

Database	Scope	Query String
IEEEXplore	Abstract	(("Abstract":traffic behavior) OR ("Abstract":traffic behaviour) OR ("Abstract":traffic regulation) OR ("Abstract":traffic safety) OR ("Abstract":traffic awareness) OR ("Abstract":traffic education)) AND (("Abstract":serious game) OR ("Abstract":game-based learning) OR ("Abstract":game based learning) OR ("Abstract":GBL) OR ("Abstract":educational game) OR ("Abstract":game) OR ("Abstract":video game) OR ("Abstract":gamification))
Scopus	Title, Keyword, Abstract	("traffic behavior" OR "traffic behaviour" OR "traffic regulation" OR "traffic safety" OR "traffic awareness" OR "traffic education") AND ("serious game" OR "game-based learning" OR "game based learning" OR "GBL" OR "educational game" OR "game" OR "video game" OR "gamification")
ScienceDirect	Full text (non-advanced search)	("traffic behavior" OR "traffic behaviour" OR "traffic education") AND ("serious game" OR "game-based learning" OR "video game" OR "gamification")

3.3. Selection Process

The search was conducted on 23 March 2025 using the query strings shown in Table 2. The search was performed in three databases: IEEE Xplore, Scopus, and ScienceDirect. IEEE Xplore returned 544 initial results, Scopus returned 234 results, and ScienceDirect returned 56 results. In total, 834 studies were identified.

After the initial search, several filters were applied to refine the results. The filtering criteria included publication year, article type, and language. First, the search results were limited to studies published between 2021 and 2025. This filter reduced the results to 215 studies from IEEE Xplore, 86 from Scopus, and 36 from ScienceDirect, for a total of 337. Second, the results were filtered by article type. Only peer-reviewed articles, such as journal and conference papers, were included. Early access articles were also included when available. This step yielded 214 studies from IEEE Xplore, 78 from Scopus, and 30 from ScienceDirect, reducing the total to 322. Finally, the results were filtered by language. Only studies published in English were included. IEEE Xplore did not require any additional filtering because it only publishes articles in English. Scopus returned 73 English studies, while all 30 ScienceDirect studies were already in English. After these filtering stages, 317 studies remained. The 317 studies were then further screened during the selection process. The detailed selection criteria are presented in Table 3.

Table 3. Inclusion and Exclusion Criteria

Inclusion	Exclusion
Studies published within the last five years, from 2021 to 2025	Studies published before 2021
Studies written in English or available in an English version	Studies not written in English and without an English version
Only one record of each study is included	Duplicate records or duplicate titles
Studies that discuss games or simulation games playable by human users	Non-game studies, such as studies on game theory or computer-based simulations without human players
Studies that focus on traffic knowledge, traffic rules, traffic safety, or traffic behavior	Studies that are not related to traffic education or road safety
Empirical studies that report the design, implementation, evaluation, or testing of a game-based application	Non-empirical studies, such as conceptual papers, reviews, editorials, or opinion papers
Peer-reviewed journal articles, conference papers, or early access articles	Articles under review, unpublished manuscripts, theses, books, book chapters, or non-peer-reviewed sources

The selection process is done in several stages. In the first stage, all duplicate titles are removed to reduce redundancy and ensure each study is considered only once during the review process. The second stage involves reading the titles, keywords, and abstracts to identify studies relevant to game-based learning or serious games in traffic education. Applications of "game theory" in self-driving vehicle algorithms, serious games about topics outside of specifically traffic rules and behavior education, such as traffic management, first-aid, monitoring pollution, or sign language, and non-playable computer simulations will be excluded. In this context, simulation games that a human player can play to simulate driving experience will also be included.

The third stage involves reading the full text to clarify studies that were previously inconclusive based on the abstract alone, to ensure they are suitable for a game-based application, and to verify whether they meet the criteria for an empirical study. In this review, a game-based application refers to an interactive digital application that uses game elements, game-based learning, gamification, or serious game principles to support traffic education. The application must allow participants to actively interact with the learning activity during the educational intervention. A study was considered empirical when it included an intervention and reported observations or measurements of its outcomes.

Figure 1 shows the selection process and the number of studies identified at each stage. Of 834 initial results, 824 studies were excluded during the selection process, leaving 10 as primary studies.

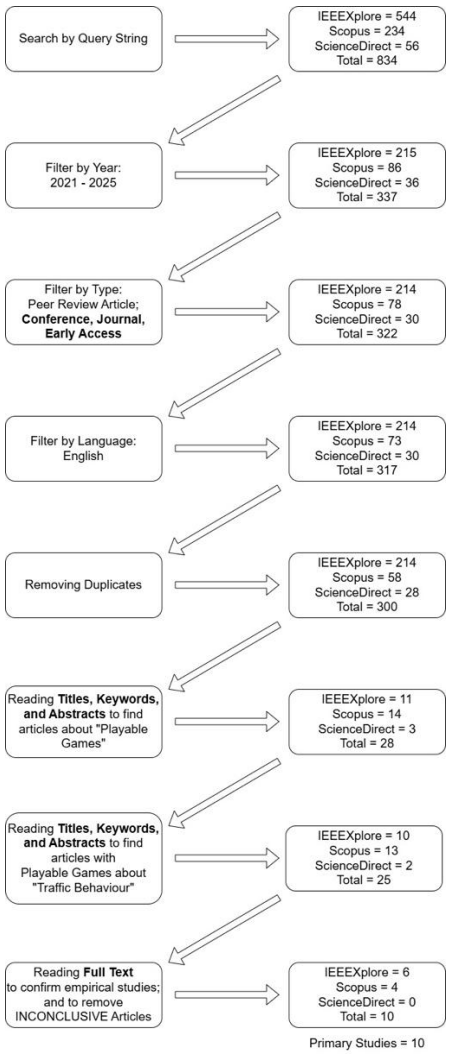

Figure 1. Selection Process

3.4. Data Extraction

Data extraction was conducted using an electronic data extraction form developed based on the research questions. The form was used to record general information from each selected study, including the title and year of publication. It also captured specific information related to the game-based approach, target users, platforms, educational content, game elements, and evaluation methods.

For RQ1, the extracted data focused on how the traffic education games were developed. This included the game-based approach, such as gamification, game-based learning, or serious games. It also included the target demographic and the platform or device used to play the game. For RQ2, the extraction focused on the educational content presented in the game. This was used to identify the traffic-related knowledge, rules, or behaviors that the game aimed to teach.

For RQ3, the form captured the game elements that support learning, such as scores, levels, timers, objectives, and other interactive features. For RQ4, the extracted data focused on the evaluation methods used in each study. The form also recorded the evaluation metrics, such as player interest, enjoyment, learning performance, or behavioral outcomes, as well as whether the reported results were positive or negative.

3.5. Analysis Method and Data Synthesis

This systematic literature review uses thematic analysis, content analysis, and descriptive statistics to analyze data from the selected studies. Thematic analysis is used to identify patterns related to the effectiveness of game-based applications in traffic education. Content analysis is used to examine the educational content and game elements presented in the serious games. Descriptive statistics are used to summarize the characteristics of the selected studies, such as publication year, target audience, platform, and evaluation method.

4. Results

4.1. RQ1: What are the characteristics of existing game-based applications for traffic education

RQ1 examines the main characteristics of traffic education games in the selected primary studies. The analysis focuses on three aspects: the game-based approach, the target demographic, and the platform used. These aspects were used to classify each game's specifications, as presented in Table 4.

Table 4. Characteristics of Existing Game-based Applications

ID	Approach	Target Demographic	Platform
ID_01	Game-based Learning (GBL)	Children	Virtual Reality
ID_02	Game-based Learning (GBL)	Children	Virtual Reality & Virtual Reality+
ID_03	Serious Game	Children	Desktop-based Application
ID_04	Game-based Learning (GBL)	Children	Virtual Reality
ID_05	Gamification	Adult	Simulation Game Kit
ID_06	Serious Game	Adult	Mobile Application
ID_07	Serious Game	Children	Virtual Reality
ID_08	Game-based Learning (GBL)	All ages	Mobile Application
ID_09	Serious Game	Children	Mobile Application
ID_10	Serious Game	Children	Desktop-based Application

In this review, the game-based approach refers to the incorporation of games or game elements into traffic education to support learning, engagement, or behavioral training. Based on this perspective, the game-based approach was classified into three categories: game-based learning, gamification, and serious games. The description for each category is as follows: (1) Game-based learning refers to a learning process that uses games to make learning more attractive, enjoyable, meaningful, and effective. It involves learning mechanisms in which students engage with educational content through gameplay [23]. (2) Gamification refers to the

use of game elements in non-game contexts to increase user motivation and engagement. In software design, gamification involves adding game elements to non-game applications to improve user experience and participation [24]. (3) Serious games refer to video games whose main purpose is not entertainment, but education or training. These games can safely simulate real-life scenarios and train users to apply specific rules or behaviors within them [25].

The target demographic was classified into three age groups. Children refer to users aged 4 to 14 years. Teenagers refer to users aged 15 to 19 years. Adults refer to users aged 20 or older. This classification was used to identify the intended users of each traffic education game.

The platform category refers to the device or system used to play the game. Virtual reality refers to a virtual or artificial environment experienced through specialized devices, mainly goggles, from a first-person perspective [26]. One study used virtual reality in combination with a web-based virtual learning environment, referred to in this review as Virtual Reality and Virtual Reality+ (VR and VR+). Desktop applications are digital games designed to be played on computers. These games include interactive features such as rules, goals, feedback, and rewards to support learning experiences [27]. Mobile applications refer to software designed for smartphones or tablets. These applications allow users to interact through touchscreen gestures and instructional prompts [28]. One study used a simulation game kit based on the FORUM8 driving simulator. This simulator features a fixed-cockpit design to represent a vehicle for right-hand drivers. It includes a steering wheel, a driving seat with a seatbelt, an accelerator, a brake pedal, and signal and wiper indicators [29].

Based on the results, most primary studies used the serious games approach, with a total of five studies that developed a full-fledged video game with educational material. Furthermore, four studies use the game-based learning approach, focusing more on learning processes in schools through video games tailored to them. Finally, only one study used the gamification approach, implementing game elements in non-game contexts. For example, article ID_05 implemented some checkpoints and written feedback into a regular driving simulator.

Regarding the target demographic, seven studies developed games for children. Other than that, two studies developed their games for adults, and one developed its game for all ages. Furthermore, most primary studies used virtual reality and mobile-based applications as their platform, totaling six studies, with three studies using virtual reality and the other three using mobile-based applications. Another platform used is a desktop-based application, or personal computers, with two studies developed their games to be played on PC. The last two studies used their own simulation game kit and VR & VR+, with one study using an entire simulation game kit and another creating a virtual learning environment for use with virtual reality devices.

4.2. RQ2: What educational goals and traffic-related content are addressed in game-based applications for traffic education?

RQ2 examines the educational goals and traffic-related content addressed in the selected game-based applications. The analysis focuses on identifying what each application aims to teach, such as traffic signs, road hazards, road-crossing behavior, pedestrian behavior, and proper driving behavior. Based on thematic analysis, the educational goals were grouped into two main categories: Behavior and Knowledge.

The Behavior category refers to goals related to behavior correction or behavior development in traffic contexts. This includes proper road-crossing behavior, such as crossing at a zebra crossing, proper driving behavior, such as driving in the correct lane, and appropriate pedestrian behavior. The Knowledge category refers to goals related to developing theoretical knowledge of traffic rules and road safety. This includes knowledge of traffic signs, traffic signals, road hazards, and other safety-related concepts.

Table 5 shows the classification of the educational goals addressed in each primary study. The results show that seven studies focused on only one category, either Behavior or Knowledge. Among these seven studies, four focused only on Behavior, while three focused only on Knowledge. The remaining three studies addressed both Behaviour and Knowledge. Overall, Behavior was addressed in seven studies, while Knowledge was addressed in six.

Table 5. The Educational Goals Addressed in Traffic Education Games

ID	Behavior	Knowledge
ID_01	✓	✓
ID_02		✓
ID_03	✓	
ID_04		✓
ID_05	✓	
ID_06	✓	✓
ID_07	✓	✓
ID_08		✓
ID_09	✓	
ID_10	✓	

4.3. RQ3: What game elements are used in game-based applications to support traffic education goals?

RQ3 examines the game elements used in the selected game-based applications for traffic education. The purpose of this analysis is to identify which game elements were reported in each primary study and how these elements were used to support the educational goals of the applications. Based on content analysis, the game elements were classified into seven categories: levels, points, puzzles, time pressure, collecting, feedback, and objectives. These categories were used because they represent explicit game design elements reported in the selected studies and are supported by definitions from previous literature.

The categories of game elements used in this review are defined as follows: (1) **Levels** refer to a set of game areas or stages with increasing difficulty progression. This category was used when a study reported that the game was structured into different stages or levels that players needed to complete [30]. (2) **Points** refer to numerical feedback given to players when they perform an action or complete a task. This category was used when a game awarded scores or points to represent player performance or progress[31] [30]. (3) **Puzzle** refers to cognitive challenges presented to players to test their knowledge. This includes activities such as quizzes, word-guessing games, or other problem-solving tasks related to traffic education [31]. (4) **Time pressure** refers to the use of a timer that requires players to act within a limited time. This category was used when time limits were included as an additional gameplay challenge [31]. (5) **Collecting** refers to a system that encourages players to collect items during gameplay. In traffic education games, this element may be used to guide players toward intended areas or behaviors, such as collecting coins placed on a zebra crossing to increase the player's score [30]. (6) **Feedback** refers to written hints or responses given to players when they make mistakes. This category was used when the game provided corrective information or guidance after incorrect actions [30]. (7) **Objectives** refer to goals or tasks that players must complete in the game. This category was used when the study reported specific missions, tasks, or end goals that determined player progress, success, or failure [30].

Table 6. Game Elements Used in Game-Based Applications for Traffic Education

ID	Levels	Points	Puzzle	Time Pressure	Collecting	Feedback	Objectives
ID_01	✓						
ID_02	✓	✓	✓	✓			
ID_03		✓			✓		✓
ID_04	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ID_05						✓	-
ID_06		✓	✓				
ID_07	✓	✓					✓
ID_08		✓					✓
ID_09		✓					✓
ID_10				✓			✓

Table 6 presents the game elements identified in each primary study. The results show that points were the most frequently reported game element, appearing in six studies. Objectives were reported in five studies. Levels were used in three studies. Puzzle and time pressure were each reported in two studies. Collecting and feedback were the least frequently reported elements, with each appearing in one study. One study did not explicitly report the use of any specific game element.

4.4. RQ4: What evaluation metrics and outcomes are used to assess game-based applications for traffic education?

RQ4 examines the evaluation metrics and reported outcomes used to assess game-based applications for traffic education. The purpose of this analysis is to identify how the selected studies measured the effectiveness of the applications as learning tools. Through thematic analysis of the evaluation methods reported in the primary studies, the metrics were grouped into four categories: Performance, Enjoyment, Replay Intention, and Application Usability.

The evaluation metrics were categorized as follows: (1) **Performance** refers to how well the game supported the learning process. This metric was identified when a study measured learning achievement or learning performance, commonly through pre-test and post-test observation. (2) **Enjoyment** refers to the players' enjoyment when using the game. This metric was identified in a study that used questionnaires to assess players' enjoyment of the game. (3) **Replay Intention** refers to the players' interest in replaying the game outside the observation or testing session. This metric was identified in a study that used questionnaires to assess players' interest in playing the game again. (4) **Application Usability** refers to the ease of use of the application. This metric was identified in a study that measured how easily players could use or interact with the game, typically through questionnaires.

The reported outcomes were then classified into three categories: Positive, Mixed, and N/A. An outcome was classified as Positive when the study reported favorable results for the metric being measured. An outcome was classified as Mixed when the reported results were varied, inconsistent, or not fully positive across the evaluated aspects. N/A was used when a metric was not measured or not reported for a specific platform or condition.

Table 7 presents the evaluation metrics and outcomes reported in each primary study. The results show that Performance and Enjoyment were the most frequently used metrics. Five studies used Performance as an evaluation metric, and all five reported positive outcomes. Another five studies used Enjoyment as a metric. Of these, three studies reported positive outcomes, while two studies reported mixed outcomes.

Table 7. Evaluation Metrics and Reported Outcomes of Game-Based Applications for Traffic Education

ID	Performance	Enjoyment	Replay Intention	Application Usability
ID_01	POSITIVE			
ID_02		VR+: MIXED VR: MIXED	VR+: MIXED VR: N/A	
ID_03	POSITIVE			
ID_04		POSITIVE	POSITIVE	MIXED
ID_05	POSITIVE			
ID_06		POSITIVE	POSITIVE	
ID_07	POSITIVE			
ID_08		POSITIVE	POSITIVE	
ID_09		MIXED		
ID_10	POSITIVE			POSITIVE

Replay Intention was used in four studies. Three studies reported positive outcomes for this metric. One study measured Replay Intention on the VR+ platform and reported mixed results. However, the same study did not measure Replay Intention for the VR platform, which

was marked as N/A. Application Usability was used in two studies. One study reported a positive outcome, while another study reported a mixed outcome.

Based on the extracted results, the studies used both learning-related and user-experience-related metrics. Performance was used to evaluate learning effectiveness, while Enjoyment, Replay Intention, and Application Usability were used to evaluate user experience with the application. The reported outcomes were mostly positive, although mixed outcomes were found in Enjoyment, Replay Intention, and Application Usability.

5. Discussion

The findings of this systematic literature review reveal that game-based applications can significantly improve traffic education by integrating interactive design elements and goal-oriented game mechanics. Elements such as Points, Levels, and Objectives are among the most utilized across the reviewed studies. These mechanics align closely with the framework by [30] and [3], which highlights how game elements can enhance user motivation, cognitive engagement, and behavioral reinforcement.

A notable observation from the selected studies is the frequent use of a results-oriented approach in implementing gamification, serious games, and game-based learning. Many applications are explicitly designed to produce measurable outcomes, whether cognitive, behavioral, or affective, by incorporating feedback mechanisms, task completion analytics, and immediate consequence-based interactions. This aligns with the findings of [23], who emphasize that effective game-based learning must balance both learning objectives and motivational design, supported by measurable performance indicators. Moreover, studies like [24] and [27] demonstrate that serious games designed with a focus on real-world transfer and measurable learning outcomes (e.g., improved decision-making in simulated traffic scenarios) are more effective than traditional learning methods alone. The combination of purposeful design and demonstrated learning outcomes indicates that serious games may indeed function as effective educational tools, capable of promoting both cognitive and behavioral development.

Aligned with this, the review identified a pattern of positive performance outcomes among users of educational traffic games. Learners demonstrated improvements in rule comprehension, decision-making accuracy, and response time in virtual environments. While some studies, such as ID_02 and ID_09, reported mixed levels of enjoyment, the overall levels of enjoyment and satisfaction remained relatively high, indicating that these tools not only facilitate learning but also support affective engagement, leading to learners' interest in repeat plays. According to [23], both performance and enjoyment are critical to sustaining attention, motivation, and long-term retention, making them equally important metrics of learning success.

Another key insight from this review is the segmentation of educational focus among the reviewed games. While some games aim to reinforce knowledge and rule comprehension, others focus on influencing real-world behavior, such as safe driving habits. This differs from the generalized assumption in earlier literature that serious games are typically holistic, addressing cognitive, behavioral, and emotional learning goals simultaneously [25]; [23].

In terms of the technology, the review reveals that mobile platforms and VR are the dominant media for delivering traffic games. This trend is supported by the increasing accessibility of mobile devices and the immersive potential of VR in simulating traffic environments. Findings by [28] confirm that even young users are increasingly adept at navigating touchscreen interfaces and interacting with guided in-game prompts, reinforcing the practicality of mobile-based educational games for early learners.

From a theoretical perspective, the results lend strong support to constructivist and experiential learning theories. The reviewed games often place users in simulated real-life scenarios, requiring them to make decisions, observe consequences, and reflect on their actions, an approach that mirrors Kolb's experiential learning cycle [32]. These interactive and immersive features enable learners to actively construct understanding, rather than passively consume information, in alignment with the principles of constructivist learning [23];[33]. Thus, game-

based tools prove especially effective for behaviorally anchored learning outcomes, particularly when designed to simulate real-world decision-making contexts.

Practically, these findings offer valuable insights for multiple stakeholders. Developers should design educational games with an emphasis on feedback loops, adaptability, and clear progression systems, as these mechanics consistently correlate with improved outcomes. Educators could adopt such tools to supplement traditional methods, particularly in contexts where experiential learning is difficult to achieve. For policymakers, the results highlight the potential of serious games to support early traffic education, especially in formal education settings and community safety programs, as demonstrated by [34]. Since children are among the primary target users of traffic education games, the findings also have practical implications for parents. Parents can play an important role in guiding children's use of these games, discussing the traffic rules and safety messages presented in the game, and reinforcing safe traffic behavior in real-life situations such as road crossing, cycling, or travelling as passengers.

The findings of this systematic literature review highlight a gap in existing research: the lack of traffic education games designed for teenagers beginning to learn to drive. This demographic represents a critical stage where foundational driving behaviors are formed. Educational games tailored to this group could support learning by teaching specific driving skills, such as overtaking, navigating T-junctions, and maneuvering through roundabouts. Developing such targeted game-based tools would not only improve driving competence among adolescents but also contribute to long-term improvements in traffic safety.

Several threats may affect the validity of this review. First, some relevant studies may not have been identified because the search was limited to IEEE Xplore, Scopus, and ScienceDirect and included only English-language studies published between 2021 and 2025. To reduce this risk, the search string combined key concepts related to traffic education and games with relevant synonyms and spelling variations, and was adjusted for each database's features. Second, the selection process may involve subjective judgment. This was mitigated by applying explicit inclusion and exclusion criteria, followed by staged screening through duplicate removal, title and abstract review, and full-text assessment. Third, bias may occur during data extraction and synthesis, particularly when classifying studies by game-based approach, target users, platforms, educational content, game elements, and evaluation outcomes. To minimize this risk, data extraction was guided by a structured form based on the research questions, while thematic analysis, content analysis, and descriptive statistics were used to support a systematic synthesis. Finally, because only ten primary studies met the criteria, the findings should be interpreted as a synthesis of recent empirical evidence rather than a complete representation of all traffic education games.

6. Conclusion

This systematic literature review examined the characteristics, educational goals, game elements, and evaluation metrics of traffic-related educational games. The findings reveal that most of the reviewed games use a serious game or game-based learning approach, primarily targeting children through mobile applications and virtual reality platforms. Educational goals are generally focused on either behavioral correction or knowledge reinforcement, with few games addressing both simultaneously. Key game elements identified include points, objectives, and levels, which support learning motivation and engagement. Commonly used evaluation metrics include performance, enjoyment, and replay intention, and most studies report positive learning outcomes.

Based on these findings, developers are encouraged to design games that integrate measurable performance feedback, engaging elements, and real-world behavior simulation. Future researchers can explore game design for teenage learners, an underrepresented yet crucial demographic in early driving education. Practitioners, including educators and policymakers, may benefit from integrating such applications into safety campaigns or school curricula to reinforce safe traffic behavior in immersive and interactive ways.

Appendix

The following list presents the primary studies included in this systematic literature review: [2], [29], [35], [36], [37], [38], [39], [40], [41], [42]. Each study is assigned an identification code from ID_01 to ID_10, which is used consistently throughout the analysis and results sections.

ID	Authors (Year)	Title
ID_1	Alyamani, H., Alharbi, N., Roboey, A., & Kavakli, M. (2023)	The Impact of Gamifications and Serious Games on Driving under Unfamiliar Traffic Regulations.
ID_2	Gounaridou, A., Siamtanidou, E., & Dimoulas, C. (2021).	A serious game for mediated education on traffic behavior and safety awareness.
ID_3	Hidayat, T. N., Purnomo, F. A., Pratisto, E. H., Nusantara, K. T., & Yudhanto, Y. (2023)	Virtual Reality-Based Traffic Sign Education for Early Childhood.
ID_4	Jaunoo, W. M., & Nagowah, L. (2022)	Trafik Moris: A Serious Game for Learning Traffic Behavior and Safety.
ID_5	Nahvi, A., & Mosharraf, M. (2023)	Implementing a Serious Traffic Game to Improve Children's Road Awareness Skills.
ID_6	Sangeetha, V., Vamsidharan, V., Saran, R., & Shrikesh, S. P. (2022)	AI Interfaced Learning Module for Road Safety using Virtual Reality.
ID_7	Theofilus, G., & Widianto, M. H. (2021)	Development of Game-Based Learning Traffic Order for Android with the Game Development Live Cycle Method.
ID_8	Vuorio, J. (2024).	Studying the Use of Virtual Reality Learning Environments to Engage School Children in Safe Cycling Education.
ID_9	Yadav, S., Chakraborty, P., Jain, K., & Jyotirmaya. (2021).	A User Centered Design Approach to Develop a Mobile App for Children.
ID_10	You, J.-W., & Lai, A.-F. (n.d.).	A Study on the Development and Evaluation of VR Learning Materials in Traffic Safety Education.

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