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Design and empirical evaluation of a web-based road safety learning platform for improving knowledge on safe driving

Reine Denientya[1*], Maya Arlini Puspasari[1], Ceria Farela Mada Tantrika[2]
[1]Department of Industrial Engineering, Universitas Indonesia, Jl. Lingkar, Pondok Cina, West Java 16424, Indonesia
[2]Department of Industrial Engineering, Khon Kaen University, 123 Moo 16, Mittraphap Rd, Khon Kaen 40002, Thailand

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ABSTRACT

Road traffic injuries remains a serious concern, particularly for young riders, who face a heightened risk of being involved in accidents. Learning can be used to teach people about road safety, yet little is known about how effective online approaches are when they incorporate games, microlearning, and user-friendly design. This study examined RideSafe, a web-based platform that teaches people about road safety through gamified lessons and a simple interface. Thirty-two university students with more than two years of experience took part and were divided into two groups. One group used RideSafe with games and short lessons. The other group used a regular online learning platform. Knowledge was tested before and after the interventions, and participants also rated the usability of each platform. The results showed that both groups showed improved knowledge, indicating that online method can help people increase road safety. However, the group that used RideSafe with games and short lessons achieved greater gains than the comparison one, suggesting that gamified and bite-sized content enhances learning effectiveness. Participants also rated RideSafe as easy to use and reported high satisfaction with its design. These findings indicate that combining games, microlearning, and intuitive design can strengthen online road safety education. RideSafe demonstrates how such learning can be made more engaging and accessible, offering a model for developing more effective road safety platforms. Continued refinement and evaluation of these approaches are recommended.

*Corresponding Author

Reine Denientya
E-mail: reinedenientya.a@gmail.com

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1. INTRODUCTION

Road traffic accidents occur on roads and involve at least one vehicle causing injury or death. In Indonesia, traffic accidents are defined as events involving vehicles or other road users that resulted in casualties or property damage. These accidents are a worldwide problem, causing approximately 1.19 million deaths every year and leaving 20–50 million people with non-fatal injuries or disabilities. Road traffic injuries are projected to increase significantly over the next decade, imposing economic losses of up to 3% of GDP in many countries. We can prevent road traffic injuries if we design transportation systems with safety in mind, focusing on people's needs [1].

Low and middle-income countries have road traffic deaths. They account for more than 92% of all road traffic fatalities worldwide [1], [2]. Indonesia is an example of this. It is an upper-middle-income country with a gross national income per person of USD 4,580, which country has a burden regarding road traffic deaths. Every year, over 120,000 accidents occur. In 2022, 27,531 deaths occurred that mainly caused by motorcycles. From the total of 148,307 accidents in 2023, 70.5% were motorcycle-related. This is because many Indonesians own motorcycles, and 85% of households in Indonesia have at least one motorcycle. The rapid growth in motorcycle ownership has increased the number of motorcycle accidents, making

road safety a major concern in Indonesia.

Young people who ride motorcycles are in a lot of danger. People between the ages of 5 and 29 years are more likely to get hurt or die in a motorcycle accident than anyone in the world. In Indonesia, many people who get hurt in motorcycle accidents are between 15 and 24 years old. When we look at the cause of the motorcycle incidents, it can be seen that the people riding the motorcycles are often the ones making mistakes. Sixty one percent of the time, it is the person who is riding the motorcycle who does something wrong. This is considerably higher than accidents caused by poor road or weather conditions (approximately 30%) and motorcycle mechanical failures (around 9%). Young motorcycle riders often do unsafe riding, such as exceeding the speed limit or not paying attention to the road [3], [4]. They might feel like they can handle anything or they might be looking for a thrill.

Often, they fail to perceive hazards on the road at all. Together, these factors increase their likelihood of being involved in an accident. The way young motocyclist think and make decisions is itself part of the problem: with a limited ability to recognize dangerous situations, they are more prone to unsafe riding behaviors. Although knowledge of motorcycle safety is important, it alone is insufficient to ensure consistently safe riding practices. Therefore, young riders need to develop critical thinking and decision-making skills to make safer judgments while riding.

Education is important for road safety. It helps people learn how to drive and not do crazy things on the road. Some researchers have questioned the effectiveness of conventional driver education programs, arguing that traditional instructional approaches often fail to actively engage learners or motivate them to adopt safe driving behaviors. In Indonesia, young people who ride motorcycles and know more about driving are less likely to be in accidents. In Indonesia, education about road safety and driving is still crucial for people to learn especially young riders [5].

The main problem is that many educational programs only provide information without encouraging learners to reflect, participate, or develop a stronger motivation to learn. Therefore, road safety education should focus not only on delivering knowledge but also on helping people become safer and more responsible drivers. Strengthening road safety knowledge is essential for reducing accidents and improving driving behavior.

Researchers have explored digital learning approaches, such as gamification and microlearning, to enhance the engagement and effectiveness of road safety education. Gamification is a way to motivate people to learn by giving them points, badges, and challenges. It encourages people to participate more because they are working toward a goal [6], [7]. This learning approach enhances learner motivation and improves knowledge retention. Sometimes, when people use gamification, they do it incorrectly, and it does not work as well. This is because they do not follow the rules of learning. Microlearning is another way to teach people things. It gives them bits of information at a time.

This approach is effective in improving knowledge retention while minimizing cognitive overload. Microlearning is helpful because it allows people to learn a bit at a time so that they can understand it better. Usability is important: when designing tools such as websites or applications, a clear and easily navigable interface helps users learn efficiently by reducing confusion. Much as well-designed map enables a traveler to find their way with ease, an intuitive learning platform allows users to focus on the content rather than the interface. Road safety education is important, and it is crucial to make it interesting and easy for people to learn it [8], [9], [10]. This can be achieved by combining gamification and microlearning with a simple and user-friendly design.

When all these things are combined, these elements can create an effective environment for young riders to learn about road safety.. Despite recent advances, few studies have looked at the integration of using small lessons, games, and designs within a single platform [11]. Most of the time, people do not really think about how this can help riders who get bored easily and do not always understand how to stay safe. This shows that we need to create digital systems for teaching road safety that are both fun and effective.

Accordingly, this study proposes that combining road safety games, microlearning, and intuitive design can enhance learning while sustaining user interest. Therefore, this study aimed to create a website that teaches road safety to riders using lessons, games, and designs that are easy to use. By putting all these things together, the platform is intended to present about road safety information in a way that is engaging, accessible, and easy to understand. This research is important because it tests whether such an approach can meaningfully improve road safety learning.

The study will also look at how using games, lessons, and accessible designs affects knowledge retention and interest in road safety. The goal is to create a web-based platform that helps people learn about road safety. This study focuses on road safety learning.

2. RELATED WORK

Road safety education is crucial for reducing traffic accidents amongst young and inexperienced riders. Some studies have shown that education can increase people's awareness of risks and improve their attitudes toward safety [3], [12]. However, it remains unclear if these programs can change people's behavior in the long run. The common limitation with driver

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education programs is that they are often unengaging and fail to involve participants actively. They also do not address the psychological reasons why people engage in risky riding behavior, such as being overconfident and unable to see hazards [3], [4]. Digital learning offers a promising means of addressing these shortcomings, and such approaches are becoming increasingly popular in road safety education. These approaches use the Internet and technology to support learning [13], [14]. They are better than classroom teaching because of the accessibility, flexibility, and far-reaching more people. Some studies have found that digital learning platforms can enhance learning outcomes and provide learning opportunities that are tailored to the individual. However, many of these systems are unengaging [14] with less interesting features that reduce their effectiveness and limit long-term knowledge retention. Given the importance of road safety education, enhancing digital learning experiences has become a promising strategy for improving learning outcomes.

Gamification is a way to get people excited about learning. It has been shown that when you add game-like things, such as points and badges, to learning, people are more likely to participate and have fun. Gamification makes learning feel like a game [11], [15]. People enjoy the challenge and the feeling of receiving rewards. This is especially true for things like road safety education, where people need to learn and practice skills. When people are learning, they need to be motivated. Gamification helps with this by making people want to keep learning and trying things out [16]. However, some studies have found that making something into a game is not enough. Learning activities need to be thought out and match what people are trying to learn. If not, gamification might not be as helpful. Another way to help people learn is microlearning. This is when information is broken down into parts so that it is easy to understand [17]. People can learn a bit at a time, which helps them remember things better. It is also good for people with attention spans because they can learn in short bursts. This learning method is especially helpful for people who like to learn in short sessions.

The good thing about microlearning is that it does not overwhelm people [18]. When there is a lot of

Table 1. Research gap analysis

Study	Approach	Strengths	Limitations	Research Gap
Akbari *et al.* [3], and Montella *et al.* [12]	Traditional Road Safety Education	Improves knowledge and awareness	Limited Behavioral Impact and Passive Learning	The need for engaging and interactive learning
Camden *et al.* [14], and Nawaz *et al.* [19]	Digital Learning Platforms	Scalable and accessible	Low engagement and interaction	Need for an engagement-driven design
Dichev & Dicheva [11], and Oliveira *et al.* [15]	Gamification in education	Increases motivation and participation in the study	Often lacks instructional depth and inconsistent learning outcomes	Need for integration with learning strategies
Jahnke *et al.* [18], and Billert *et al.* [6]	Microlearning approaches	Enhances retention and reduces cognitive load	Limited interaction and engagement features	Need for integration with engagement mechanisms
Group Nielsen Norman [13]	UI/UX Design in Learning Systems	Improves usability and accessibility	Does not directly address the effectiveness of learning	Need for integration with pedagogy
Le *et al.* [16]	Gamification in the context of road safety	Improves traffic knowledge and skills	Focuses mainly on gamification without integration	Need for a holistic learning system
This study	Integrated microlearning + gamification + UI/UX	Combines engagement, usability, and effectiveness of learning		Addresses theoretical and methodological gaps

informations, it can be difficult to learn. With microlearning, people can learn a little bit and then come back later, which makes it easier to perceive and remember. Some studies have already shown that microlearning works well, especially when it is used with technology [6]. However, it is important to ensure that the information is presented in a sensible and understandable way.

In addition to teaching methods, how a digital learning system looks and feels is also very important. Research shows that when digital learning systems are easy to use, with menus and a consistent design, people learn better and with less effort. A designed system helps users focus on learning rather than figuring out how to use it. This makes learning more efficient. For example, a good system can help people learn quickly. On the other hand, a bad system can make it difficult for people to use the platform. This can cause stress. Make people less interested even if the learning material is good.

Most people study gamification, microlearning, and user interface design separately. Not many people have looked at how to combine these things into one learning platform for teaching road safety. Many studies only look at whether people like using a system or if it is easy to use. They do not check whether people actually learn more. This creates a problem because we do not know how to make learning platforms that work. To solve this problem, this study combines microlearning, gamification, and a good user interface design into one web-based platform. Then, it checks if the web can help people learn more about road safety. This study is different because it examines how all these things work to help people learn. The goal is to see if a fun website, easy to use, and well designed can help people learn how to drive safely. A comparison of studies is shown in Table 1.

3. RESEARCH METHODS

3.1. System interaction flow and sequence of learning

The proposed system is a web-based learning platform designed to provide users with a structured learning experience. The learning process consists of several sequential stages, including user registration, course selection, a pre-course assessment, self-paced learning activities, and a post-course assessment. This structured approach is intended to guide learners through the course content systematically while maintaining their engagement throughout the learning process.

The website also tells people how they are doing so that they can get better at the things they are trying to learn. There are games and fun things on the website that make learning fun. The system also breaks down the things that people need to learn into pieces so that it is not too much to handle. The website looks the same everywhere so people can easily understand what is going on and use it. The learning platform comprises the learning process. The main parts of the website and how it all works are shown in Fig. 1. The learning platform has a learning process that includes the learning flow and its main components.

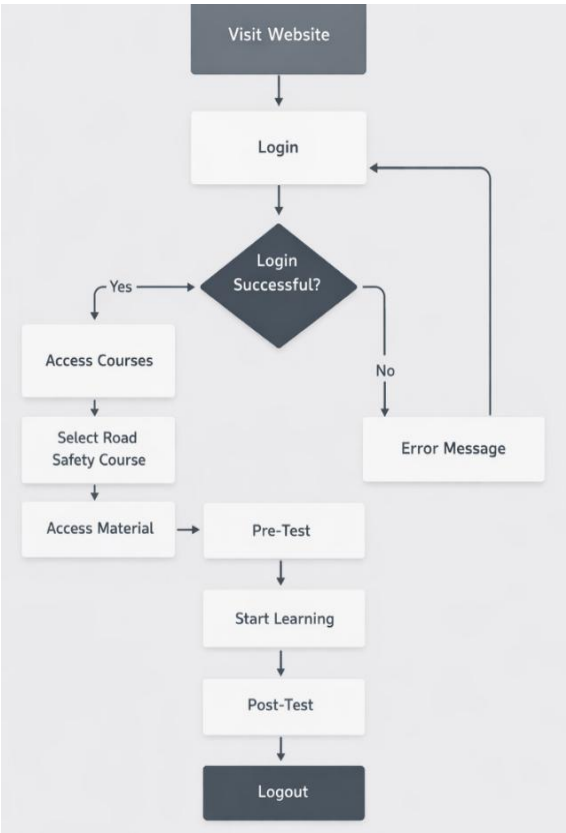


Fig. 1. Overall system interaction flow

3.2. Gamification design framework

The idea of making things like a game was considered using the elemental tetrad framework. This framework has four parts that work together: story, how things work, how things look and feel, and technology. The framework is about ensuring that the story, the rules, and the technology all fit together to keep people interested [16], [20]. The author used the framework to add game-like elements to the learning process. They added things like points, badges, and challenges to the learning to make people want to keep going. They also added story elements and feedback to help people understand how they are doing [21]. The aim was to foster intrinsic motivation alongside extrinsic rewards: the narrative and achievement systems encouraged sustained engagement, and the feedback mechanisms gave learners a clear sense of how they were progressing.

3.3. Development of learning systems and platform implementation

The RideSafe learning platform was created using WordPress, which has many tools to help people learn.

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LearnDash was used to structure the courses into clear and easy–to–follow modules, which gamified elements such as points and rewards to encourage participation. H5P was used to create fun activities, such as quizzes and interactive books [13]. The course is divided into four parts: traffic ethics, riding knowledge, hazard perception, and safety control. Each part has interactive elements to help people learn and remember. The platform is like a game which has rewards that make people want to finish the course. Experts in road safety and transportation engineering checked the course materials. Course materials were reviewed by experts in road safety and transportation engineering, who evaluated the content for relevance, clarity, and accuracy and confirmed that it aligned with established traffic safety rules and the platform's educational objectives. Their feedback was incorporated to refine the course prior to release, ensuring that RideSafe is a reliable and effective learning tool for its users.

3.4. UI/UX principles

To make things easier to use and understand when people are learning, we used some ideas from the UX Laws to design the interface. We chose six ideas to build into the system: Hick's Law, Jakob's Law, the Law of Common Region, the Serial-Position Effect, Miller's Law, and the esthetic–Usability Effect [22]. We put these ideas into action by making the navigation simple, keeping the interface consistent, grouping parts together, making sure the most important things stand out, and making everything look nice and neat. The goal was to help people learn efficiently by eliminating unnecessary complexity and making it easier for them to understand the information when using the platform. The way the interface looks is not only about how it appears but also about making sure it is easy to use and helps people learn, which are things we can measure and see if they are working or not.

3.5. Pilot testing of usability and iterative refinement

We conducted some testing to determine how easy it is for people to use the system. Six people tried it out. We used a test called the System Usability Scale to determine how easy the system is to use. This test has ten questions, and people can answer them on a scale of one to five. We also used the Questionnaire for User Interaction Satisfaction to determine if people are happy with the system. This test looks at things such as how easy the system is to learn and if the information it gives is useful. We also asked people to tell us what they think about the system so that we can improve it. The System Usability Scale and Questionnaire for User Interaction Satisfaction helped us understand what people like and dislike about the system.

The time we tested our system, we found that people were getting confused because the instructions were not clear, the text was hard to read, and it was not easy for them to get started. Therefore, we made some changes to our system. We made the instructions clearer, the text bigger, and the system simpler. We have added a feature that helps people get started [23], [24]. We then tested our system again to determine if the changes we made were helpful. We performed this test to ensure that our system was easy to use before we performed a test to determine if it really works. We are only talking about how easy our system is to use so we can make sure it is ready for the larger test.

3.6. Experimental design

This study used a method to determine if the new learning platform is good. The participants were split into two groups: one group used the platform with fun games and short lessons, and the other used the old way of learning. The study was conducted on a computer over three days from May 31 to June 4, 2024. To see what the participants learned, they took a test before they started and another test after they finished. The participants were given rules to follow so that everything was fair. They had to have an internet connection turn on their camera work by themselves and show their screen while they took the tests. This was done so that everyone could learn and take the tests. The main thing the study wanted to determine is if the new learning platform is better than the way of learning on the computer. This study looked at the learning platform and the old way of learning to see which one works better. The main thing being tested was the new learning platform to determine if it helps people learn more than the way.

3.7. Participants and determination of sample size

A total of 32 university students participated in this and were randomly assigned to two groups of 16 participants each. Eligibility criteria required participants to have at least two years of motorcycle riding experience and to be familiar with the use of online learning platforms. The sample size was determined based on recommendations from a previous study, which suggested a minimum of 12 participants per group. To account for potential participant attrition, the number of participants in each group was increased beyond the minimum requirement. G*Power was also used to check if our sample size was adequate for comparing the two groups. We assumed a medium effect size of 0.5, a significance level of 0.05, and a desired statistical power of 0.80. Based on these calculations, we needed 27 participants. Because we had 32 participants, we met the statistical requirement to detect meaningful differences between groups.

We chose university students for this study because young riders are often involved in motorcycle accidents. However, this means that our findings might not apply to all groups of people. For our study, we

focused on university students. University students are a group most probably involved in motorcycle accidents. Our study only looked at university students, which might limit the applicability of our findings to other populations. Although the participant sample was limited to university students, university students represent one of the risk demographic groups in motorcycle-related traffic accidents. Nevertheless, the restricted demographic scope may limit the generalizability of the findings to populations.

3.8. Measures and statistical analyses were performed

To evaluate the effectiveness of the RideSafe learning modules, the authors administered a post-learning assessment to participants upon completion of the program. The assessment consisted of 10 questions designed to measure participants' knowledge of road safety. The questions were divided into four parts: traffic ethics, riding knowledge, hazard perception, and safety control. These parts were chosen because they teach the RideSafe learning modules. The people who conducted the test wanted to make sure it was a test. So they had two experts look at it. These experts know a lot about transportation safety and how to teach people things.

The authors looked at the test questions to determine if they were relevant and clear and if they matched what the RideSafe learning modules teach. They wanted to make sure that the test questions were good. The experts provided feedback on the test questions. The test was changed to improve it. This was done to ensure that the test measured what people learned from the RideSafe learning modules. The test was designed to determine whether people learned the facts from the RideSafe learning modules. The test was not designed to determine what people were thinking or feeling.

As a preliminary study, the authors did not conduct a comprehensive psychometric evaluation of the assessment instrument. Instead, the test underwent expert review to establish content validity by ensuring that its items were aligned with the learning objectives of the RideSafe modules. The assessment was developed based on the module content to evaluate participants' understanding of the material. The authors acknowledged that future research should perform more rigorous validation procedures to further establish the reliability and validity of the instrument. The assessment results were subsequently analyzed to determine the significance of the learning outcomes. They used a number called a significance level to determine whether the results were important. This value was 0.05. They also performed some tests to see if the results were real.

One of these tests was the Shapiro–Wilk test. This test was used because there were no people in the study. They also used Levene's test to see if the results were the same for everyone. They looked at the test results to determine if the people who used the RideSafe learning modules learned something. They compared the results of the previous tests. After people used the modules to see if there was a difference. They also compared the results of people who used the modules to those who did not. They used a measure called Cohen's d effect size to determine whether the difference was large or small. The RideSafe learning modules were used to teach people about road safety. The people who conducted the study wanted to see if the modules were working. They used the tests to see if people learned something from the RideSafe learning modules. The RideSafe learning modules are important because they teach people about road safety.

This study was conducted to determine if the RideSafe learning modules are effective. The people who conducted the study think that the modules are a way to teach people about road safety. They believe that the RideSafe learning modules should be used to teach people about road safety. The RideSafe learning modules provide a way to learn about road safety. The people who made the study used the results of the tests to determine the effectiveness of the RideSafe learning modules. They think that the modules are effective because the users learned something. The RideSafe learning modules are a way to learn about road safety because they teach people about traffic ethics, riding knowledge, hazard perception, and safety control.

3.9. Instrument validation and measurement considerations

The instrument in this study was designed to determine how well people understand road safety concepts. It comprised 10 questions covering four areas: traffic ethics, riding knowledge, hazard perception, and safety control. These areas were chosen to match what people should learn from the RideSafe platform. To establish content validity, the test was reviewed by two experts in transportation safety and education, who examined each item for relevance, clarity, and alignment with the intended learning outcomes. The test was changed at times based on what the experts said to make the questions clearer and easier to understand.

Because this study was small in circle, not all measures of test quality were undertaken. The instrument was not evaluated for its ability to capture constructs such as behavior or attitudes toward road safety; rather it was used primarily to determine whether participants gained knowledge from the ridesafe platform. Therefore, the results of this study should be looked at as a way to see if the RideSafe platform works in the future. Future research should incorporate more rigorous validation procedures, including assessments of the test's reliability (e.g. internal consistency) and its construct validity in measuring road safety knowledge.

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4. RESULTS AND DISCUSSION

4.1. System design and learning platform

The system design phase involved taking the idea and turning it into a website that people can actually use to learn new things. This website is called RideSafe. RideSafe is built using Wordpress with added tools such as LearnDash, GamiPress, and H5P to optimize the usage. The aim is to make RideSafe a place where people can learn things in a fun way and where they can see how they are doing

Users register and login, where they can take courses on RideSafe, do a test, and finally take another test on RideSafe. These sequences allow learners to progress in a structured, step-by-step manner without confusion. RideSafe is designed to help people learn things and have a good experience.

Fig. 2 shows the page of the RideSafe platform that features a clean, simple, and intuitive layout that helps users quickly locate what they need and navigate with ease. The main page of the RideSafe platform contains information about the platform and links to lessons. It has an overview of how the lessons on the RideSafe platform are set up. This helps users get around the site quickly.

The lessons are divided into four topics: traffic ethics, riding knowledge, hazard perception, and safety control. The RideSafe platform has lessons and interactive parts to help people learn. These lessons are not just things to look at. They are meant to help people learn at a time through short and interactive activities. We added quizzes and other interactive items to the lessons so that users can take part in learning and remember what they learned. The RideSafe platform uses these parts to help people better learn and remember things.

The safety control modules (Fig. 3, Fig. 4, and Fig. 5) are about being aware of safety and understanding what is happening around you. These safety control modules are meant to help riders with things they are not good at, such as thinking about risks and seeing hazards coming. This has been discussed in other studies, such as Akbari *et al*. [3] and Ali *et al*. [4]. The platform is not only about showing information but also has things like points and badges to make it fun. There are challenges and stories that keep people interested and make them want to keep learning. The platform provides people with feedback so that they know how they are doing. This is part of the platform's learning process. The learning process is important to keep people engaged and make them want to continue using the platform. The platform is not about giving rewards to people; it is about helping people who want to keep learning and improve with the platform.

The user interface was developed according to established usability principles. To avoid overwhelming users with excessive choices, the interface was kept deliberately simple, in line with what Hick's Law says to do. Familiar design conventions

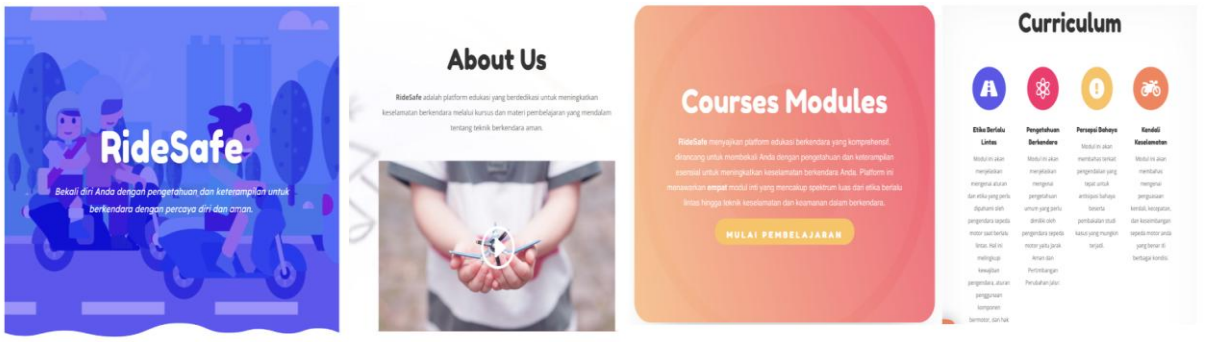


Fig. 2. Display of the learning site start page



Fig. 3. Third lesson page view (perception of danger)



Fig. 4. Fourth lesson page view (safety control)

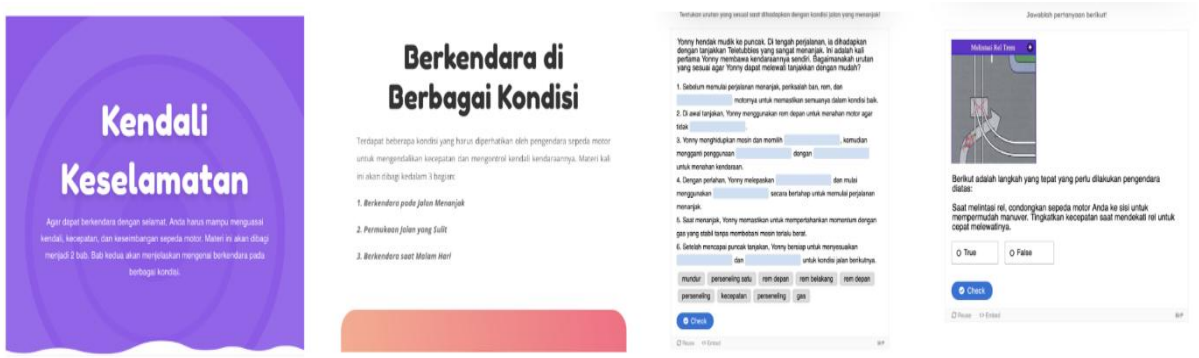


Fig. 5. Page view of the fourth lesson (part two safety control)

were adopted, such as Jakob's Law, and related elements are grouped together on the platform, as the Law of Common Region says, as can be seen in Fig. 6 and Fig. 7 of the platform. The layout also drew on Miller's Law and the serial-position effect to make the information on the platform easier to understand and remember.

The system architecture consists of teaching methods, game-like elements, and interactive technology and design that is user-focused. This system is supposed to make people want to learn and make it easy for them to use and understand the information. The main goal of the system architecture is to improve digital road safety education by putting all these things.

The system architecture combines teaching and gamification with interactive technology and design that is focused on the user to create a place where people can learn. The system architecture helps people want to learn, makes it easy for them to use, and helps them understand the information better so that road safety education can be improved. The system architecture aims to improve road safety education by combining teaching and game-like elements with interactive technology and design that is focused on the user.

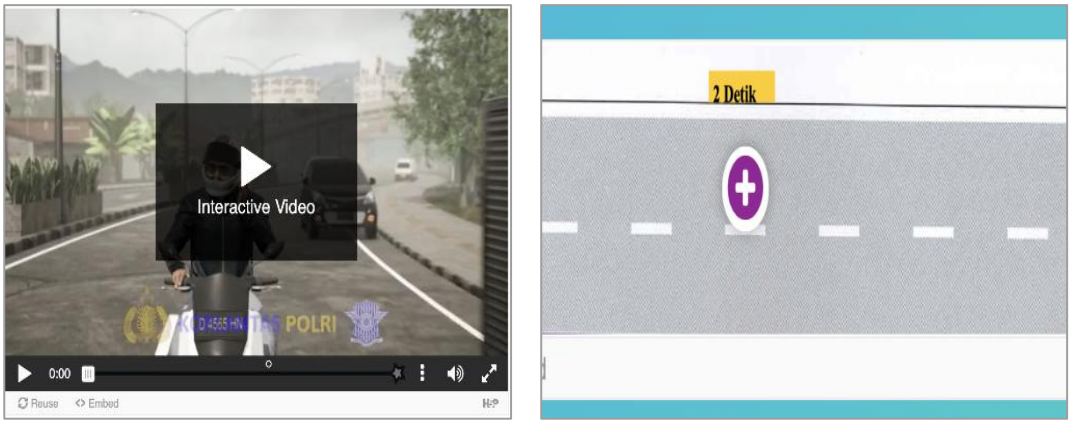


Fig. 6. Play and magnify buttons on the sites

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Table 2. Selection of colors, fonts, and other site features

Aspects	Details	Reason/Justification
Color Usage	Blue (#007BFF)	Navigation and primary buttons are used to improve readability and provide a professional appearance
	Green (#28A745)	Confirmation and progression elements to symbolize safety and convenience
	Yellow (#FFC107)	Used for notifications and attention-oriented information
	Red (#DC3545)	Used for warnings and indications of errors
	Teal (#009688)	Applied in the HPM to improve focus and visual comfort
	Orange (#FF7043)	Used in the traffic ethics module to increase enthusiasm for learning
	Pink (#E91E63)	Used in the driving knowledge module to improve learner engagement
	Purple (#9C27B0)	Used in the safety control module to create an authoritative and engaging learning environment
Typography	Sans-serif (AbeeZee)	Selected to improve readability and maintain visual clarity on digital screens
Font Size	Heading: 24–36 pages; Content: 14–18 pages	Structured Hierarchy Improves Navigation and Information Prioritization
Navigation	Breadcrumbs, clear buttons, and dropdown menus	Supports intuitive navigation and reduces interaction errors
Responsive Design	Desktop, tablet, and mobile support	Improves accessibility and multi-device usability
Accessibility	Alt text, high contrast, ARIA landmarks	Supports inclusive interaction and compliance with accessibility
Performance	Image optimization, caching, and minimized code	Improves page loading speed and interaction efficiency

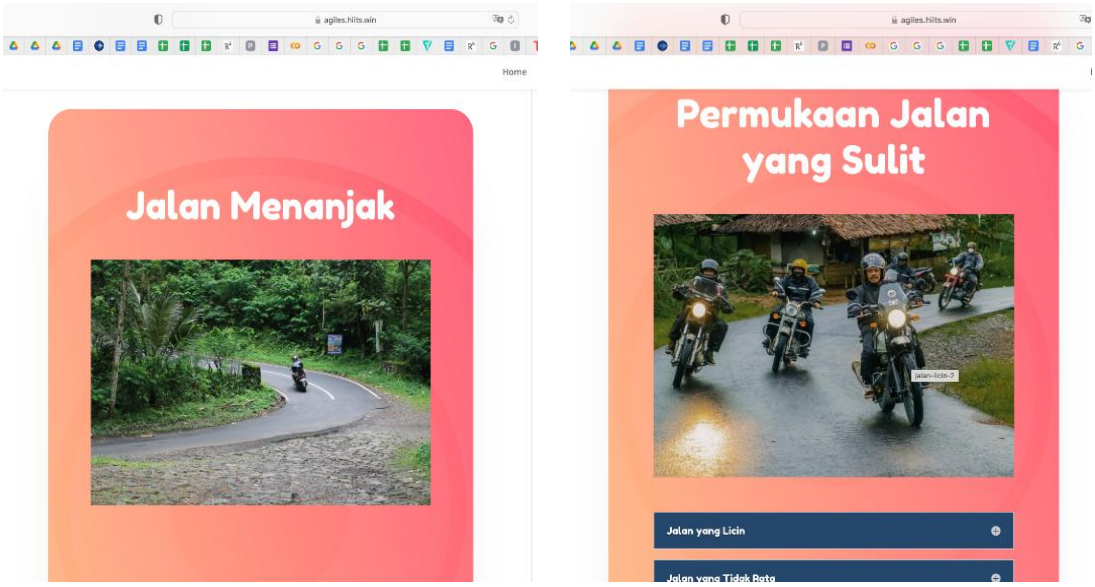


Fig. 7. Implementation of the common region law

4.2. Website design outcomes and user interface/UX-oriented development

The design plans shown in Table 2 were chosen for a specific reason, to look good and be easy to use. The design plans were made to be simple so that people can learn from them without getting confused. Familiar colors were chosen in a way that makes sense so that people can see what is what. Legible fonts were

selected and the navigation menus were kept uniform to prevent users from becoming disoriented. The interface was designed to be responsive, functioning effectively on desktop computers, tablets, and smartphones. Accessibility is also considered, as alternative text was added to image users with visual impairments, and a balanced color scheme (neither overly bright or dull) was applied to ensure visual comfort. All these things help people use the system without getting frustrated. The design plans in Table 2 really help with this.

4.3. UI/UX validation through usability testing

Table 3 summarizes the initial SUS evaluation results for the RideSafe platform. The findings indicate moderate usability, with the highest score in applicability and confidence, while improvement in ease of use is still required. Table 4 shows the first QUIS test results.

Table 3. Summary of the initial SUS evaluation results

SUS Dimension	Average Score
Ease of Use	2.83
Applicability and confidence	3.67
Overall perceived usability	3.25

Table 4. Summary of the initial QUIS evaluation results

QUIS Dimension	Average Score
Overall Feeling	2.61
Perceptual Experience	3.75
Learning Experience	2.92
Connectivity with Life	4.33

Table 5 summarizes the initial SUS evaluation results for the RideSafe platform. The findings indicate moderate usability, with the highest score in applicability and confidence, while improvement in ease of use is still required.

Table 5. Summary of the initial user feedback and interface refinement priorities

Aspect	Summary
Design Elements	Improved clarity and visual consistency
Design Consistency	Colors, shapes, and interface components are standardized.
Navigation Flow	Clearer icons and onboarding guidance were added.
Interactive Content	Maintained engaging interactive activities.
Learning Materials	Comprehensive instructional materials were maintained.

After testing, some changes were made to the interface to improve it. These changes included making the font easier to read, making it look nicer, helping users know what to do, and making it clearer how to move. We then updated the SUS results, as shown in Table 6.

Table 6. Second iteration SUS evaluation results

SUS Dimension	Average Score
Ease of Use	3.28
Applicability and confidence	4.00
Overall perceived usability	3.64

The second SUS test showed that people found it easier to use, had trouble, and felt more confident when using the platform. The interface was also more consistent. The updated QUIS test also showed improvements in how users interact with the platform. These improvements are presented in Table 7. These findings suggest that refining the platform based on what users think makes it better for people to use and helps them learn things on the RideSafe platform.

Table 7. Summary of the second iteration QUIS evaluation results

QUIS Dimension	Average Score
Overall Feeling	2.33
Perceptual Experience	4.17
Learning Experience	3.67
Connectivity with Life	4.08

4.4. Learning effectiveness: Pre-and post-test outcomes

Learning effectiveness was assessed by administering tests to participants before and after the training. Both experimental and control groups completed these pre-tests and post-tests. Table 8 shows the results of these tests for the group and the control group. Table 8 shows details about how the experimental and control groups learned. It shows what the experimental and control groups knew before and after the training.

Table 8. Descriptive statistics of the learning outcomes

Group	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Gain
Control Group	34.75 ± 14.14	53.00 ± 23.70	18.25
Experimental Group	38.38 ± 19.09	70.13 ± 15.31	31.75

The results show that both groups improved after the learning intervention. However, the experimental group performed a lot better on the post-test, indicating more knowledge retention than the control group. The experimental group got a post-test score of 70.13, but the control group only got 53.00. The experimental

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Table 9. Summary of the statistical assumption testing

Statistical Test	Variable	Statistic	p-value	Interpretation
Shapiro–Wilk	PreTest_CG	0.9607	0.6755	Normal
Shapiro–Wilk	PostTest_CG	0.8920	0.0602	Normal
Shapiro–Wilk	PreTest_EG	0.9613	0.6271	Normal
Shapiro–Wilk	PostTest_EG	0.9281	0.2279	Normal
Levene's Test	Pre-Test	0.7425	0.3957	Homogeneous
Levene's Test	Post-Test	2.4757	0.1261	Homogeneous

Table 10. Paired-sample t-test results

Group	Mean Difference	SD	t	df	p-value
Control Group	18.25	31.33	-2.556	15	0.0395
Experimental Group	31.75	24.15	-4.969	15	0.0001

Table 11. Independent-samples t-test results

Variable	t	df	p-value	Interpretation
Pre-Test	0.6100	30	0.5462	No significant difference
Post-Test	2.4279	30	0.0214	Significant difference

group also learned more with a gain score of 31.75 compared with 18.25 for the control group. This means that the gamified microlearning intervention helped people learn.

A comparison of both tests indicated that the people in the group generally did better on the post-test and learned more consistently than the people in the control group. Groups equivalence was first verified prior to interventions: an independent-samples t-test on the pretest scores and found no significant difference between the groups.

A paired-sample t-test was conducted to determine if people improved from the pre-test to the post-test. Results shows that both groups improved, though the gain in control group was modest, whereas the experimental group indicates substantially greater improvement. Finally, and independent-samples t-test was performed on the post-test scores, resulting in a better performance of the experimental group. This means that the people who used the gamified microlearning intervention learned more than the people who did not.

4.5. Statistical evidence of learning gains and between-group differences

Before interpreting the results, the data were checked to see if the numbers were normally spread out and if the groups were similar. The Shapiro–Wilk test indicated that all data sets were normally distributed, satisfying the assumptions for parametric testing. The Levenes test is also assesed to check if the groups had amounts of variation, and this test showed that the groups had similar variation for both the data collected before and after the test (Table 9).

The test results showed that people got better at things after being taught. This was the case for both the group and the control group. The experimental group learned more than the control group. The difference between the scores before and after the test was significant for the group. The experimental group had greater learning gains than the control group (Table 10). Further independent-samples analysis on post-test scores demonstrated superior learning performance under the experimental conditions (Table 11).

The results show that the game-like learning method was good for learning things, and people learned more from it than from the regular teaching method. The game-like learning method really helped people gain knowledge. This is because the game-like learning method was more fun and people were more interested in it than the method. The game, like the learning method, is a way to learn new things because it is fun and works.

4.6. Discussion

This study checked how well RideSafe worked. RideSafe is a website that teaches people about road safety. Games, short lessons, and easy-to-use design Both groups learned more about road safety after using RideSafe. The group that used the gamified version learned more than the other groups [22], [25]. [26]. The website was also improved over time. This made it easier and more fun to use. This likely helped people to learn more. Road safety education is important. It should be made stronger and not stopped. Just because someone has riding experience does not mean they are safe because they might not know about hazards and risks. Therefore, road safety education is necessary for people to learn and prevent accidents.

The relatively low pretest scores observed in both groups indicate that young riders may still possess limited road safety knowledge despite having more than two years of riding experience [27]. This finding reinforces prior studies that riding experience alone

does not necessarily correspond to adequate hazard perception, risk awareness, or safe decision-making ability [12]. Young riders frequently demonstrate confidence in vehicle operation while underestimating traffic risks and safety-oriented cognitive processes. Consequently, improving road safety knowledge and risk perception remains essential not only for educational purposes but also as a preventive educational strategy that may support safety awareness and safer decision-making processes among high-risk riders.

The significant improvement observed between the pre- and post-test assessments in both groups further confirms that structured road safety education can positively contribute to knowledge acquisition and safety awareness development. Educational interventions incorporating behavioral and cognitive components, such as hazard recognition and risk perception training, have been shown to support cognitive readiness and potentially contribute to safer decision-making processes [28]. Furthermore, the use of digital learning platforms helps overcome the limitations commonly associated with traditional educational approaches, particularly constraints related to accessibility, time, and geographical reach [13], [19]. This advantage is particularly relevant in countries with high levels of motorcycle usage and limited access to CRT programs.

A central finding of this study is that the gamified learning condition produced significantly stronger learning outcomes than the non-gamified instructional approach. Although previous studies have widely acknowledged the role of gamification in improving learner engagement and participation [11], [15], the present findings indicate that gamification may also contribute positively to measurable learning effectiveness in road safety education [29]. Unlike earlier studies, which frequently implemented gamification as an isolated motivational feature, the present study integrated gamification with microlearning strategies and user-centered UI/UX principles within a unified instructional environment. This integrated approach may explain the stronger learning outcomes observed in the experimental group, as motivational support, cognitive efficiency, and usability optimization were simultaneously facilitated throughout the learning process.

The findings can be interpreted using behavioral learning theory and SDT. Gamification mechanisms, such as points, badges, progression systems, and immediate feedback, may reinforce learner motivation, competence perception, and sustained participation during learning activities. These features encourage repeated interaction and active engagement, which support deeper information processing and memory retention. Therefore, the findings support previous research that reinforcement, interaction, and feedback mechanisms play an important role in shaping learning effectiveness and behavioral adaptation [5].

The implementation of microlearning may also have contributed substantially to the observed learning improvements. The platform reduced excessive cognitive burden and enabled gradual information processing by presenting instructional content in short and focused segments. This instructional approach aligns with cognitive load theory, which emphasizes the importance of minimizing unnecessary mental effort to optimize learning performance [14], [23]. In road safety education, segmented learning delivery may help users better recognize hazards, process traffic-related information more efficiently, and improve situational awareness during decision-making activities.

UI/UX quality also played a crucial role in supporting the effectiveness of learning within the RideSafe platform. Iterative usability refinement improved the clarity of the interface, navigation consistency, and interaction efficiency, thereby reducing unnecessary cognitive effort during system use. A well-designed interface allows learners to focus more effectively on instructional content than on operational complexity. Furthermore, accessibility-oriented interface implementation improved inclusivity and interaction comfort across different devices and user conditions [30]. These findings indicate that UI/UX design should not be treated solely as a visual component but as an essential factor influencing cognitive efficiency, usability performance, and learning engagement in DESs. The observed improvements in usability may also have contributed indirectly to the stronger learning outcomes identified in the experimental condition. Improved interface clarity, navigation consistency, and interaction efficiency can reduce unnecessary cognitive effort during system use, thereby allowing learners to allocate more attention to instructional content processing and task engagement.

The findings that digital road safety education platforms integrating gamification, microlearning, and user-centered design can function as promising and scalable learning solutions for improving road safety knowledge acquisition. Compared with conventional awareness-based educational approaches that often rely on passive information delivery, the integrated model implemented in this study provides a more interactive, cognitively supportive, and engagement-oriented learning environment. The results further highlight that effective road safety education may require not only accessible instructional content but also motivational and cognitive support mechanisms embedded within the learning system.

Nevertheless, several limitations should be acknowledged. First, the participant sample was limited to university students, which may restrict the generalizability of the findings to broader demographic groups and real-world riding populations. Second, the intervention period was relatively short and primarily

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focused on knowledge acquisition rather than long-term behavioral outcomes. Third, the study evaluated learning effectiveness within a controlled educational environment and did not directly measure actual riding behavior in real traffic situations. Another limitation of this study is the absence of platform engagement analytics such as session duration, interaction frequency, and time-on-task measurements. Because the intervention was conducted asynchronously, differences in learning outcomes may have been partially influenced by variations in participant engagement intensity rather than solely by the instructional mechanisms of gamification. Therefore, future studies should incorporate detailed engagement tracking and learning analytics to provide a more precise interpretation of instructional effectiveness. Future studies are also recommended to involve more diverse participant groups, longer intervention durations, behavioral outcome measurements, and real-world riding assessments to further validate the effectiveness of integrated digital road safety education systems.

4.7. Research implications

This study is important for people who create road safety education systems. First, computer programs for learning should be interactive and easy to use because they can help people learn better. Schools and governments might want to use computer programs that are similar to games instead of just teaching in a classroom.

Second, learning about road safety on a computer or phone can help people who do not have access to road safety programs. RideSafe shows that computer programs can teach people about safety in a standardized and easy-to-access manner. Road safety education should not only teach people about traffic rules. Also about recognizing hazards and making good decisions. In the future, computer programs should be developed that can adjust to the person and help them learn over a long time.

Third, the RideSafe platform's web-based implementation demonstrates the potential scalability and accessibility of digital road safety education. Compared with conventional face-to-face instruction, web-based learning environments can provide broader access, flexible learning opportunities, and more continuous educational exposure [13], [19]. This characteristic is particularly relevant for countries with high motorcycle dependency and limited access to structured safety education programs.

The findings also provide implications for government-led public safety initiatives and transportation education policies. Integrated digital learning platforms may serve as complementary tools to support licensing programs, awareness campaigns, and road safety education interventions. Standardized digital education systems can facilitate the wider dissemination of safety-related knowledge while maintaining consistency across different user groups.

This study highlights the importance of incorporating behavioral and cognitive principles into the design of educational systems. Effective road safety education should extend beyond knowledge transfer and support safety awareness, risk perception development, and decision-making preparedness among young riders [12]. Therefore, the results reinforce the importance of designing educational interventions that simultaneously address motivational, cognitive, and usability dimensions. This research provides a foundation for future investigations exploring long-term educational and behavioral outcomes, adaptive learning mechanisms, real-world driving data integration, and the effectiveness of digital road safety interventions across broader demographic populations. Future studies may also examine how personalized gamification strategies and AIS influence sustained learner engagement and long-term educational outcomes.

5. CONCLUSION

This study investigated the effectiveness of RideSafe, a web-based road safety learning platform that integrates gamification, microlearning, and user-centered UI/UX design principles. The findings demonstrate that both experimental conditions significantly improved the road safety knowledge of the participants following the learning intervention. However, participants exposed to the gamified microlearning environment achieved substantially greater learning gains than those receiving non-gamified instruction, indicating that the integration of gamification mechanisms within structured microlearning environments positively contributes to the effectiveness of learning about digital road safety.

The study further demonstrates that effective digital road safety education requires not only accessible instructional content but also motivational, cognitive, and usability-oriented learning support mechanisms. The combined implementation of gamification features, segmented instructional delivery, and user-centered interface refinement improved learner engagement, interaction quality, and knowledge acquisition performance. Additionally, iterative usability evaluations using SUS and QUIS revealed measurable improvements in navigation clarity, interface consistency, interaction efficiency, and overall user satisfaction following UI/UX refinement processes. These findings highlight the importance of integrating PD with usability-oriented interface development to support more effective technology-mediated learning experiences.

The findings support the view that engagement-oriented instructional design, cognitive load reduction,

and motivational reinforcement can improve digital learning effectiveness. Unlike previous studies that frequently examined gamification, microlearning, or UI/UX design separately, this study demonstrates the potential benefits of integrating these approaches within a unified educational platform. Therefore, this study contributes to the growing body of research on digital learning environments by providing empirical evidence regarding the instructional value of combining motivational, cognitive, and usability dimensions in road safety education systems.

Nevertheless, several limitations should be acknowledged. First, this study primarily evaluated short-term knowledge acquisition and did not directly assess long-term knowledge retention or actual behavioral change in real-world riding contexts. Second, the participant sample was limited to university students, which may restrict the generalizability of the findings to broader demographic populations. Third, the intervention period was relatively short, and sustained long-term engagement patterns were not evaluated comprehensively. In addition, the absence of platform engagement analytics, such as session duration, interaction frequency, and time-on-task measurements, limited the ability to isolate the instructional effects of gamification from differences in participant engagement intensity during asynchronous learning activities. Consequently, the findings should be interpreted primarily within the scope of short-term educational effectiveness and controlled digital learning evaluation settings.

Therefore, it is recommended that future research involve larger and more diverse participant groups, conduct longitudinal evaluations examining long-term learning retention and educational or behavioral outcomes, and incorporate detailed engagement analytics to improve the interpretation of instructional effectiveness. Further studies may also explore adaptive learning mechanisms, personalized gamification strategies, and interdisciplinary approaches integrating educational psychology, behavioral science, and learning technology to develop more robust, scalable, and evidence-driven digital road safety education interventions.

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