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Evaluating the Effectiveness of an Online Gamified Traffic Safety Education Platform for Adolescent Motorcyclists in Pakistan

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Abstract: This study explores the potential of online traffic safety education for adolescent motorcyclists in Pakistan. An e-learning platform, "Route 2 School" (R2S), was developed focusing on traffic knowledge, situation awareness, risk detection, and risk management. Male students (14–18 years) who commute to school by motorcycle were divided into an experimental group (EG) and a control group (CG), both completing pre- and post-measurement questionnaires. The EG showed significant improvement in knowledge, risk detection, and risk management compared to the CG, but not in situation awareness. Participants reported increased traffic safety awareness and suggested adding more interactive elements. The R2S platform's scores revealed better performance in risk detection and risk management modules than situation awareness. Time spent on modules varied, with situation awareness requiring the most time. Adolescents expressed satisfaction with the platform, acknowledging its role in increasing traffic awareness. This study provides initial insights into the effectiveness of online traffic safety education in Pakistan, highlighting the potential to address the lack of comprehensive traffic safety education in schools. Further research and stakeholder engagement are recommended to integrate such platforms into formal education, potentially reducing traffic-related injuries among adolescent motorcyclists in developing countries.

Keywords: traffic education; adolescents; traffic safety; adolescent motorcyclists; online/e-learning platform; gamification; Pakistan

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1. Introduction

Around the world, more than 1.19 million people die in traffic-related incidents each year, with low- and middle-income countries disproportionately affected [1], with motorcyclists (30%) accounting for almost one-third of these deaths [1]. Due to their inherent vulnerability and lack of protection, motorcyclists are among the most at risk for injuries on the road [2–4]. For instance, the death rate for motorcycle riders is 28 times higher than for car passengers [5]. Researchers have argued that little research has taken place to date that focuses on vulnerable road users [6,7]. However, countries worldwide are now initiating traffic safety programs to eliminate fatalities and severe injuries; for example, the United States has taken a Vision Zero for their transportation systems [8].

According to the World Health Organization [9], one of the leading causes of death among 5–29-year-olds is road accidents. Research in the United States found that children aged 5 to 13 who went to school by walk or cycle are at greater risk of injury than those who do not walk or cycle to school [10]. There are several risk factors that, when combined, increase the risk of children in traffic; these risk factors are both physical and behavioral [11]. One physical factor is the children's small posture, which makes it difficult to see the incoming traffic [12]. Another physical disadvantage is their limited ability to coordinate eyesight and hearing, resulting in them overlooking potentially dangerous situations and increasing the probability of road accidents [13]. Important behavioral factors are their ability to scan the environment while on the road, inconsistency in judgment, mainly in young age groups [14], distraction using mobile phones in traffic situations, and less

developed hazard perception skills [15–18]. These abilities, however, improve with age and traffic experience. To ensure that all children attain a specific skill level, traffic safety education can help keep children safe in traffic [12].

1.1. Traffic Safety Education and Gamification

Traffic safety education is a critical component in reducing road traffic injuries and fatalities. It is also one of the 5 E's of traffic safety: Encouragement, Enforcement, Evaluation, Engineering, and Education [19]. Research conducted on traffic accidents has found that human factors contribute significantly to road accidents and outweigh environmental and vehicle factors [20]. Due to a lack of knowledge about traffic safety, the number of traffic injuries among children increased significantly [21]. Therefore, traffic education is necessary for children to increase their knowledge about traffic safety and reduce risky behavior. Education not only increases the safe movement of children but also transfers the survival techniques among them. In order to make traffic safety education more effective, an effective educational method can be created.

Apart from increasing knowledge, children must identify dangerous situations while being on the road. Situation awareness focuses on teaching road users to effectively perceive and comprehend their surroundings and make informed decisions while navigating traffic. Enhancing situation awareness among participants can potentially reduce accident risks [22].

Another factor that can reduce traffic incidents is risk detection. It refers to the identification and assessment of incidents taking place on the road and recognizing them as hazards [22]. Effective risk detection relies on a combination of perceptual skills, cognitive processing, and experience. However, to increase overall road safety, risk detection skills must be improved through education, training, and technology.

In addition to risk detection, effective risk management is essential for mitigating the impact of potential hazards in the traffic environment. It refers to the ability of road users to handle risky traffic situations. The main aim of risk management is to minimize the frequency and magnitude of accidents [23]. It also requires continuous monitoring and evaluation to ensure the effectiveness of implemented measures.

In terms of learning methods used by teachers in school, traditional methods are considered ineffective and boring by many students [11]. Research has shown that the major problem among children is a lack of motivation and engagement [24], and game-like elements can enhance engagement among children. The concept of gamification is not new in classrooms, as mentioned above, but its amalgamation with digital learning can help increase engagement and motivation among users. Gamification can be defined as "embedding game features into activities which are not games themselves" [25]. Examples of game features are points, levels, and badges.

1.2. Evaluation of Traffic Safety Education

Traffic safety education has been recognized as a critical approach to reducing road traffic accidents [26–28]. It is vital for all road users because all participants are equally accountable for traffic safety. In the past, mostly in developed countries, traffic safety education was essential in educating children in schools [29]. A national study conducted in Spain [30] among primary school students (47.5%) and secondary school students (40.7%) revealed that traffic safety education statistically influenced risky traffic behaviors of children and adolescents (e.g., children crossing the road at traffic signals, using a cell phone while walking, etc.). There was a link between age-observed behavior and attitudes toward traffic safety. Regarding behavior and attitude, the study investigated the self-reported behavior of adolescents (e.g., I should cross the road when the signal is blinking). As a result, the study indicates the importance of the educational system's involvement in strengthening children's road safety skills early in life.

Recently, a study was conducted to evaluate traffic safety education in collaboration with the government and motorcycle manufacturers to promote sustainable motorcycle

culture in Vietnam [31]. The study mainly focused on the riders' attitudes, accident prevention behavior, and psychological changes after participating in traffic safety education. The investigation was carried out to comprehend the social implications of cross-sector collaborative education and its influence on participants' overall well-being. This study also reveals the missing contents in the present motorcycle rider training program and encourages stakeholder participation and cooperation. The study included around 500 motorcycle and 100 non-motorcycle users aged between 20 and 40 to evaluate the traffic safety knowledge among both groups. The results revealed that experienced riders better understand traffic safety than novice riders after following the traffic safety education. Also, novice riders with fewer than three years of experience had a higher tendency to show unsafe behavior, whereas experienced riders had better risk awareness and hazard perception skills.

1.3. Gamification in Road Safety Education: Enhancing Engagement and Learning Outcomes

Gamification, the application of game-design elements and game principles in non-game contexts, has emerged as a promising approach to road safety education [32,33]. As education evolves in the digital era, gamification emerges as a vital tool for modernizing teaching methods [34]. Research has demonstrated that gamification elements in e-learning platforms can enhance learner engagement and performance [24,35]. Specifically, points and progress bars are usually shown to improve performance and increase retention within e-learning environments [36]. Furthermore, digital badges positively influence user engagement and performance [37]. By incorporating elements such as points, badges, leaderboards, and interactive scenarios, gamified road safety education programs can increase engagement, motivation, and knowledge retention among learners, particularly adolescents [38].

Gamified approaches in road safety education have shown the potential to improve various aspects of traffic safety knowledge and skills. For instance, studies have demonstrated that gamification can enhance hazard perception skills, increase awareness of traffic rules, and promote safer attitudes toward driving and road use [39,40]. The interactive nature of gamified platforms allows learners to experience realistic traffic scenarios in a safe, virtual environment, facilitating experiential learning and decision-making skills crucial for road safety [11].

Moreover, gamification can address the challenge of maintaining learner interest in traditionally dry or repetitive safety content. Gamified road safety education can substitute long-term engagement and behavioral change by providing immediate feedback, rewards for progress, and a sense of achievement [41].

1.4. Traffic Safety Education in Pakistan

Pakistan is the sixth largest country in the world, having a population of more than 222 million [42]. Regarding road traffic accidents in Pakistan, around 16% occurred among children and adolescents aged between 5 and 19 [43]. There is an alarming rise in road traffic accidents mainly due to a phenomenal increase in motor vehicles [44]. Pakistan has seen significant growth (268%) in the number of registered motor vehicles, mainly motorcycles (613 percent), in the last ten years [45]. According to statistics from 2018, motorcycles make up about 74% of all registered vehicles in Pakistan [46].

Globally, the rising use of motorcycles causes far more fatal road incidents than other motor vehicles. Since motorcycle riders are vulnerable road users, most motorcycle accidents result in severe injuries [47]. Most motorcycle riders do not adhere to traffic laws since their driving licenses were not issued with sufficient examination, leaving most of them without knowledge of the rules [44]. In mega cities of Pakistan, there are extremely few alternative and convenient transportation options, making motorcycles an accessible and affordable method of transportation for the lower middle class [48]. Specifically in Lahore, motorcyclists were found to be the most vulnerable users (61%), with most accidents occurring due to a collision with another vehicle (45%) [49].

In addition, research was conducted in Karachi about injuries among children younger than 15 years. The authors extracted the data from the emergency transport services [50]. The retrospective study was carried out of injured children transported by emergency transport. The result showed that most of the injuries were caused by motorcycle crashes, i.e., 80% of the injuries were among children, and most were males in those injuries. The study also highlights that enforcing driving laws and child safety education could reduce causalities and injuries. A recent survey in Karachi revealed that students between 13 and 17 years old are more exposed to traffic injuries while riding a motorbike, mainly due to unawareness of traffic rules and regulations [51]. Hence, this indicates that education targeting knowledge about traffic rules and regulations is essential.

Scarce studies have been conducted in Pakistan about traffic safety education for children. To our knowledge, one study explored the possibilities of traffic safety education conducted in Karachi. The study investigated a book to improve the understanding of road traffic injuries among school children [52]. The target group for this study was fourth- and fifth-grade students aged 8–12 years old. The colorful bilingual (Urdu and English) storybook was used for an interactive discussion about traffic safety. The results show increased knowledge among children after the post-test, indicating that this kind of storybook can be valuable to add to the curriculum. The possibilities of online traffic safety education in Pakistan have yet to be investigated, while online education has several benefits compared to classroom education. One of the primary benefits is flexibility, which allows students to work at their own pace and schedule, balancing work or other commitments [53]. Additionally, online education provides immediate feedback and assessments through analytics tools and automated grading systems, allowing students to assess their progress and learning skills immediately [54].

1.5. Objectives and Research Questions

Except for the study of [52], which investigated classroom-based traffic education, and a pilot study conducted in one of the schools of Lahore to teach traffic rules to children [55], no studies conducted in Pakistan evaluated the possibilities of traffic safety education for children going to school. As a result, studies have yet to explore the possibilities of online education. Therefore, this study aims to explore the use of an online traffic educational platform in Pakistan among adolescents on knowledge improvement and users' opinions. The study developed and evaluated traffic safety education for adolescents going to school on motorcycles.

The target group consisted of adolescents aged 14–18 years because they are more vulnerable to road traffic injuries as they have easy access to motorcycles in Pakistan [45]. The evaluation used an EG, a CG, and a pre- and post-questionnaire. The study explored four research questions:

- Research question 1: What are the participants' scores and time investment across the different modules of the platform?
- Research question 2: To what extent do participants' knowledge, situation awareness, risk detection, and risk management skills differ at the pre-measurement stage?
- Research question 3: What improvements in knowledge, situation awareness, risk detection, and risk management are observed after using the platform?
- Research question 4: What are participants' opinions about the usability and effectiveness of the platform?

2. Materials and Methods

2.1. Development of the Online Platform

The study selected a modular object-oriented dynamic learning environment (Moodle), a learning management system (LMS) that may be used to launch e-learning programs. Many e-learning content developers have chosen this LMS to host their course materials for online learning [56–58], as Moodle is free and open-source available online. The online platform was developed based on the online platform R2S of Belgium [11].

It was designed using Moodle, an open-source learning management system (LMS). The platform consists of four modules, i.e., traffic knowledge, situation awareness, risk management, and risk detection. Each module was built to address the specific learning outcomes regarding road safety.

2.1.1. Knowledge Module

The knowledge module assesses the understanding and comprehension of traffic laws and regulations. It mainly focuses on the fundamental rules and regulations of traffic, including road signs and legal requirements for motorcyclists [59]. The main aim of the module was to check the knowledge of participants on the basis of ten questions. Also, the feedback related to the question is provided soon after the participants answer the questions where additional explanation is given about the correct answer.

2.1.2. Situation Awareness Module

The situation awareness module is concerned with raising awareness of various traffic situations. It mainly educates learners on recognizing and interpreting various traffic situations, especially at intersections and crossings. The module emphasizes the importance of being aware of road elements like traffic lights, signs, etc., and other road users, including pedestrians, cars, fellow motorcyclists, etc. It consists of ten questions related to different traffic scenarios. The feedback was also displayed after each question given by the participants. It can improve participants' understanding of different traffic situations.

2.1.3. Risk Detection Module

The risk detection module was developed to detect the skills of risk detection among the participants. The main aim of this module was to help the participants identify the potential hazards in traffic scenarios. Here, the hotspot questions were introduced to the participants, and they were shown in ten different images with the box on three different locations within each image. The participants need to select the correct box where the attention needs to be paid first. Additionally, feedback was given after every question to further explain why it was the correct answer.

2.1.4. Risk Management Module

Responding to a hazard in a given traffic condition is part of risk management. It mainly teaches the strategies for safely navigating through hazardous situations, emphasizing decision-making skills in high-risk scenarios. Here, the ten questions with multiple-choice answers were displayed along with the images to visualize the situation. The feedback was also given here after every question to make the participants aware of different traffic situations and deal with them accordingly.

Research has shown that adolescents are primarily involved in accidents near intersections and crossings [60]. Therefore, the platform mainly focused on these situations. The course was organized within Moodle by creating separate sections for each module. Additionally, to develop interactive content, including different traffic scenarios and quizzes, Adobe Captivate (version 11.8) was used. It was then incorporated via SCORM packages into Moodle. In order to access the content of the platform, participants needed to log in first. They received the login information from their school representative, who received it from the platform administrator. Once logged in, the participant could access the content of each module. Each module has ten questions, and the adolescents will receive 10 points per question if they give the correct answer and zero points if they give a wrong answer. Hence, the maximum score that adolescents can receive is 100, and the minimum score is zero. Based on their performances and for future motivation, badges were awarded (gold, silver, bronze, and completion badges).

The footage was collected by capturing pictures via a rider's view in different traffic situations, as shown in Figure 1. As mentioned above, the images were then used to

make the modules using Adobe Captivate. The red box (Figure 1b) shows an example used for risk detection, where respondents are required to choose (from three options) whether the situation depicted poses a risk for riders. While, the yellow arrow (Figure 1a) is used in the knowledge module to assess the respondents' understanding of traffic signs. In total, 40 questions were filled by adolescents at home instead of at school due to COVID-19 restrictions.

Figure 1. Examples of different traffic scenarios in the online platform: (**a**) shows the knowledge question about the traffic sign, (**b**) shows the risk detection question about paying attention while on the road, (**c**) shows the risk management questions about doing best while entering the main road, (**d**) shows the situation awareness questions about identifying elements while riding a motorcycle.

2.2. Pedagogical Design Elements in the Platform

The e-learning platform was designed with several pedagogical principles in mind, including active learning, immediate feedback, gamification, and structural learning path.

2.2.1. Active Learning

Each module incorporated interactive scenarios [61] that required students to actively engage and participate in the content, promoting a deeper understanding of the platform.

2.2.2. Immediate Feedback

Scenario-based questions in all modules provided instant feedback [62], allowing participants to recognize their mistakes and correct them.

2.2.3. Gamification

To motivate participants and enhance their engagement [39], the platform incorporated gamified elements such as points, badges, timer, and levels. This approach aligns with the concept of "learning through play" [63], making the educational content more engaging and potentially improving knowledge retention through enjoyable and game-like interaction.

2.2.4. Structural Learning Path

The platform was designed with a structural learning path [64] that gradually increases with difficulty. Firstly, the initial module covered basic traffic safety knowledge, while later modules introduced more complex scenarios and higher-level decision-making. This increased difficulty ensured that participants pushed them to improve their risk detection and management skills.

2.3. Gamification of the Learning Platform

To enhance the engagement and motivation of students to follow the platform, gamification elements were incorporated into the design of the platform. For the current study, gamification elements like points, levels, badges, characters, progress bar, and timer are incorporated. The point system was introduced so that participants feel a sense of accomplishment while completing each module. Each module is considered a level, and there are four levels (four modules). The participants need to go through these levels in sequence to complete the platform. In addition to this, participants received digital badges (gold, silver, bronze, and completion badges) based on their performance in each module. These badges acted as a reward for the participants and encouraged them to strive for better results. A character named "Abdullah" was used as a source of identification factor for the adolescents as they could relate to him as an adolescent of their age going to school. A progress bar was also used for each module so that participants were aware of how much progress they had made in each module. Lastly, the timer was set in the situation awareness module so that the participants had limited time (15 s) to see the scenario-based traffic picture and identify elements they had seen in that picture.

In addition to the gamification elements for motivation, gamification mechanics, i.e., progression and reward, were also kept in mind while designing a platform. The participants had to complete one module before progressing to the next. This created a structured learning path that kept them aware and engaged throughout the program. Also, each module comes with progressively difficult challenges, with rewards (points, levels, and badges) given on the successful completion of each module. This also kept them motivated and engaged. Gamification not only made the learning experience more enjoyable but also improved knowledge retention and behavioral outcomes, such as better risk detection and risk management in real-world scenarios.

2.4. Questionnaires

Each group (i.e., EG and CG) completed two measurement questionnaires (a pre-measurement and a post-measurement questionnaire). The questionnaire was developed using an online survey platform, Qualtrics [65]. The pre-measurement questionnaire was the same for both CG and EG. It had two parts: the first part included demographic questions like gender and age, while the second part consisted of two questions related to each module included in the platform (knowledge, situation awareness, risk detection, and risk management) and two questions related to each module but not included in the platform. It can be seen in Appendix A.

The post-measurement questionnaire was the same as the pre-measurement questionnaires for CG; however, the EG also included 5-point Likert scale questions about the platform, for example, 'Did you like the platform?', with answers going from "extremely satisfied" to "extremely dissatisfied". The EG completed the pre-measurement questionnaire the same day before the platform, whereas the CG only completed the pre-measurement

questionnaire. CG and EG were asked the post-measurement question after one week of the pre-measurement questionnaire. The data were collected in April and May 2022.

2.5. Selected Schools and Sample Size

The target group consisted of students who went to school with a motorcycle. Although getting a riding license in Pakistan is 18 years, underage motorcycle driving is prevalent [51]. Therefore, participants were between 14 and 18 years old, studying 9th and 10th grade. Since male adolescents ride motorcycles to school in Pakistan [54], only male adolescents were recruited for this study. Participants participated voluntarily. The study was conducted among students from two different schools in Lahore. One school was labeled a CG, and the other an EG.

2.6. Analysis

Data were analyzed in SPSS (IBM Statistics 18) using independent samples t-tests in which "Group" (i.e., CG, EG) was added in grouping variables, and the questions of the pre-measurement and post-measurement questionnaire (i.e., questions that were part of the platform and the questions that were not part of the platform of each module) were added as a dependent variable. Levene's test for equality of variances was tested to determine whether there is a significant difference among the variables. Only the corrected F and probability values were reported. Moreover, a descriptive analysis was also performed to find the scores the adolescents received while doing the pre- and post-measurement questionnaire and for the EG while using the platform. A significance level of 0.05 was maintained for all the statistical tests.

3. Results

3.1. Demographic Analysis

A total of 69 adolescents from the EG registered for the platform, but only 35 started the platform. Hence, there was a drop-out of 49.28%. Of these 35 participants, 26 completed the whole platform; hence, there was a response rate of 74.29%. For the pre- and post-measurement questionnaires, 69 adolescents from the EG have filled out the pre-measurement questionnaire, and 39 adolescents have filled out the post-measurement questionnaire. Whereas from the CG, 29 adolescents filled out the pre-measurement questionnaire, and 12 adolescents filled out the post-measurement questionnaire. See Table 1 for the distribution per grade.

Table 1. Demographic statistics of schools.

Group	Grade	Number of Pre-Measurements Questionnaires (%)	Number of Post-Measurement Questionnaires (%)
EG	9th grade	18 (26.09)	18 (46.15)
	10th grade	51 (73.91)	21 (53.85)
	Total	69 (100)	39 (100)
CG	9th grade	10 (34.48)	4 (33.33)
	10th grade	19 (65.52)	8 (66.67)
	Total	29 (100)	12 (100)

3.2. Traffic-Related Behavior and Knowledge among Adolescents

The data reveal that a significant number of students rely on motorbikes as their primary mode of transport to school, with nearly three-quarters using them regularly. Despite this, nearly nine out of ten, the overwhelming majority, do not possess a driving license, indicating that many students will likely operate these vehicles without proper legal authorization. This lack of licensing is concerning, particularly given that about two-thirds of students reported involvement in at least one traffic fine or accident, and close to one-fifth have been involved in multiple incidents. These figures suggest that students frequently

engage in risky traffic behaviors, potentially due to inadequate knowledge or disregard for traffic regulations. Moreover, while only a small portion admitted to committing traffic offenses, a significant number were unsure, hinting at either a lack of awareness about what constitutes a traffic offense or a reluctance to disclose their involvement fully.

In terms of self-assessed traffic knowledge and skills, the majority of students view themselves positively. Over half believe they have "Good" traffic knowledge, and nearly half rate their traffic skills similarly. However, the high incidence of traffic violations and accidents contradicts this self-assessment, suggesting a possible overestimation of their abilities or a gap between theoretical knowledge and practical application. A small but notable proportion of students rated their knowledge and skills as "Neutral", "Bad", or "Very Bad", indicating that while many feel confident, some recognize their deficiencies. The overall findings point to a need for enhanced traffic education and stricter enforcement of traffic laws to bridge the gap between perceived and actual traffic competence among students. See Table 2 for the summary of traffic-related behavior and knowledge among adolescents.

Table 2. Summary of traffic-related behavior and knowledge among adolescents.

Category	Response	Count	Percentage (%)
Mode of Transport to School	On Foot	5	13.16
	Cycle	0	0
	Motorbike	29	76.32
	Others	4	10.53
Possession of a Driving License	Yes	4	11.11
	No	32	88.89
Involvement in Traffic Fine/Accident	1	24	63.16
	2	7	18.42
	More than 2	7	18.42
Involvement in Traffic Offence	Yes	5	13.51
	No	22	59.46
	Maybe	10	27.03
Self-Assessment of Traffic Knowledge	Very Good	5	13.16
	Good	21	55.26
	Neutral	8	21.05
	Bad	3	7.89
	Very Bad	1	2.63
Self-Assessment of Traffic Skills	Very Good	8	21.62
	Good	16	43.24
	Neutral	9	24.32
	Bad	3	8.11
	Very Bad	1	2.7

3.3. Research Question 1: What Are the Participants' Scores and Time Investment across the Different Modules of the Platform?

The scores on the EG platform were relatively high, as shown in Table 3. The table shows the minimum and maximum scores obtained by the adolescents in each module. The results reveal a mixed performance across the four modules assessed. Risk detection and risk management demonstrate better overall performance, with risk management achieving the highest average score. However, situation awareness emerges as a significant area of concern, with the lowest average score and highest variability, indicating a widespread need for improvement in this crucial skill.

Table 3. Scores value of all the modules in the platform.

Modules	Mean	N	Std. Deviation	Minimum	Maximum
Knowledge	60.29	35	15.80	10	90
Situation Awareness	33.60	25	27.21	0	80
Risk Detection	62.59	27	26.68	10	100
Risk Management	65.38	26	24.53	0	100
Total	56.43	115	26.02	0	100

N = *number of respondents*.

Similarly, Table 4 shows the time spent by the adolescents per question in each module. Knowledge and risk management questions are answered relatively quickly (15 and 13 s, respectively), aligning with the consistent and high performance in these areas. Risk detection takes slightly longer at 25 s. The module where the adolescents spent the most time was the situation awareness module (98 s/question on average).

Table 4. Time spent per question in each module.

Modules	Time (s)
Knowledge	15
Situation Awareness	98
Risk Detection	25
Risk Management	13

3.4. Research Question 2: To What Extent Do Participants' Knowledge, Situation Awareness, Risk Detection, and Risk Management Skills Differ at the Pre-Measurement Stage?

These two tables (Tables 5 and 6) present pre-measurement questionnaire results comparing both groups' (CG and EG) responses across four modules: knowledge, risk detection, situation awareness, and risk management. Table 5 shows responses to "Within Platform Questions" (Questions 1 and 2), while Table 6 displays "Outside Platform Questions" (Questions 3 and 4).

Table 5. Mean scores of within-platform questions from pre-measurement (CG and EG).

Module	Groups	Question 1		Question 2	
		F (*p*-value)	Mean (SD)	F (*p*-value)	Mean (SD)
Knowledge	CG EG	0.02 (0.87)	1.29 (0.46) 1.30 (0.46)	1.57 (0.21)	1.14 (0.36) 1.10 (0.30)
Risk Detection	CG EG	1.42 (0.23)	1.55 (0.50) 1.63 (0.48)	0.07 (0.78)	1.40 (0.50) 1.60 (4.49)
Situation Awareness	CG EG	0.76 (0.38)	1.72 (0.45) 1.68 (0.46)	0.73 (0.39)	1.58 (0.50) 1.63 (0.48)
Risk Management	CG EG	0.01 (0.93)	1.44 (0.50) 1.44 (0.50)	3.33 (0.07)	1.25 (0.44) 1.34 (0.47)

For the within-platform questions, there are no statistically significant differences between CG and EG across all modules and questions, as indicated by *p*-values greater than 0.05. For outside-platform questions, there are almost no statistically significant differences between the two groups, except for two questions.

Table 6. Mean scores of outside-platform questions from pre-measurement (CG and EG).

Module	Groups	Question 3		Question 4	
		F (*p*-value)	Mean (SD)	F (*p*-value)	Mean (SD)
Knowledge	CG EG	0.15 (0.69)	1.68 (0.47) 1.71 (0.45)	0.41 (0.52)	1.48 (0.50) 1.56 (0.49)
Risk Detection	CG EG	6.75 (0.01) *	1.33 (0.48) 1.46 (0.50)	0.06 (0.79)	1.51 (0.50) 1.53 (0.50)
Situation Awareness	CG EG	3.83 (0.05) *	1.75 (0.43) 1.66 (0.47)	0.15 (0.69)	1.58 (0.50) 1.56 (0.49)
Risk Management	CG EG	0.33 (0.56)	1.27 (0.45) 1.30 (0.46)	0.34 (0.55)	1.27 (0.45) 1.24 (0.43)

* $p \leq 0.05$.

3.5. Research Question 3: What Improvements in Knowledge, Situation Awareness, Risk Detection, and Risk Management Are Observed after Using the Platform?

An independent sample t-test was performed on both CG and EG's post-measurement questionnaire, and most of the questions showed a significant difference among the scores. For knowledge questions that were part of the platform, there was a substantial difference in one of the questions (While riding a bike, what is most important to do?). However, scores were substantially different for both questions that were not part of the platform. It shows that after doing the module, the EG group performed better than CG on post-measurement questions.

For risk detection questions, there was a significant difference between one of the questions, for both within-platform and outside-platform questions. Moreover, there was no significant difference in risk management and situation awareness between questions that were part of the platform and questions that were not. The mean scores, standard deviation (SD), F value, and *p*-value can be seen in Tables 7 and 8.

Table 7. Mean scores of within-platform questions from post-measurement (CG and EG).

Module	Groups	Question 1		Question 2	
		F (*p*-value)	Mean (SD)	F (*p*-value)	Mean (SD)
Knowledge	CG EG	0.38 (0.53)	1.33 (0.49) 1.28 (0.45)	5.7 (0.02) *	1.25 (0.45) 1.10 (0.30)
Risk Detection	CG EG	4.70 (0.03) *	1.50 (0.50) 1.23 (0.42)	1.23 (0.27)	1.41 (0.51) 1.30 (0.46)
Situation Awareness	CG EG	0.38 (0.53)	1.58 (0.51) 1.53 (0.50)	0.38 (0.53)	1.58 (0.51) 1.46 (0.50)
Risk Management	CG EG	0.86 (0.35)	1.33 (0.49) 1.25 (0.44)	3.70 (0.06)	1.41 (0.51) 1.23 (0.42)

* $p \leq 0.05$.

Table 8. Mean scores of outside-platform questions from post-measurement (CG and EG).

Module	Groups	Question 3		Question 4	
		F (*p*-value)	Mean (SD)	F (*p*-value)	Mean (SD)
Knowledge	CG EG	5.02 (0.03) *	1.41 (0.51) 1.20 (0.40)	3.80 (0.05) *	1.33 (0.49) 1.17 (0.38)
Risk Detection	CG EG	6.14 (0.01) *	1.50 (0.52) 1.20 (0.40)	2.70 (0.10)	1.50 (0.52) 1.28 (0.45)
Situation Awareness	CG EG	0.64 (0.42)	1.50 (0.52) 1.38 (0.49)	0.06 (0.94)	1.41 (0.51) 1.41 (0.49)
Risk Management	CG EG	1.56 (0.21)	1.33 (0.49) 1.23 (0.42)	0.86 (0.35)	1.33 (0.49) 1.25 (0.44)

* $p \leq 0.05$.

3.6. Research Question 4: What Are Participants' Opinions about the Usability and Effectiveness of the Platform?

The questions related to the R2S platform were asked at the end of the post-measurement questionnaire to the EG. Most of the adolescents were satisfied with the R2S platform and their questions. Also, adolescents found it helpful to increase their awareness of traffic knowledge and road safety. They also like the badges they receive according to their performance on the platform. They have also agreed that going through this platform has increased their knowledge of traffic. They were also satisfied with the feedback after every question; it helped them understand the module questions. However, they have suggested including videos instead of only pictures to be more realistic and closer to real-life scenarios. In addition to this, they have also indicated that making it short and precise would make it time-efficient. Overall, they were satisfied with the R2S platform, which helped them increase traffic awareness. Figure 2 shows the opinion of adolescents from EG regarding questions about the platform.

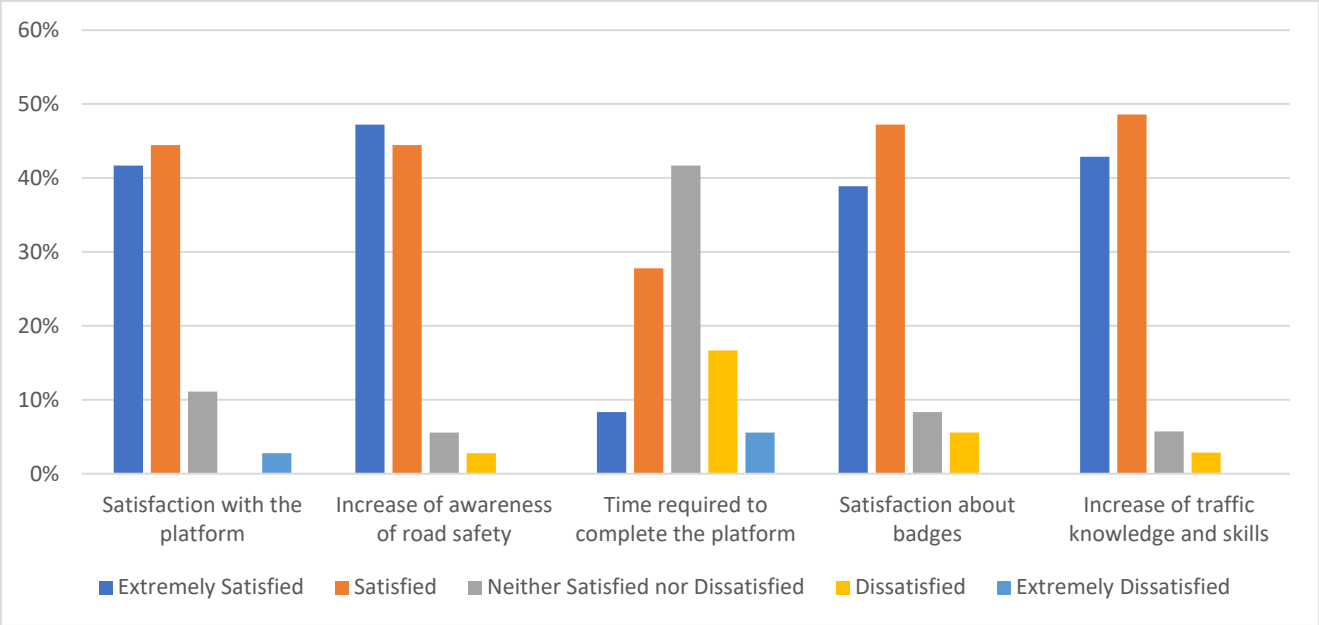

Figure 2. Opinion of adolescents regarding questions about the platform.

4. Discussion

The primary goal of this study was to investigate the possibilities of an online traffic safety education platform in Pakistan among adolescents, focusing on improvement in traffic knowledge and skills (i.e., situation awareness, risk detection, and risk management) and user opinions. Therefore, an EG and a CG were selected for this research, and pre- and post-measurement questionnaires were completed.

4.1. Scores and Time Investment on the Platform

The study found that most adolescents find the module related to situation awareness the most difficult among all the modules on the platform. This difficulty arises from identifying various traffic elements within a limited time of 15 s per picture. It is essential to mention that the mean score of the situation awareness module is below average (33.60) compared to the other three modules, indicating its difficulty for adolescents. A similar study in Belgium also revealed that the mean value of the situation module is lower than that of the other three modules [11]. On the other hand, adolescents performed better in the other modules as they were more familiar with the multiple-choice questions used.

Knowing traffic rules and recognizing traffic signs can provide a safer experience for adolescents [66]. Therefore, besides teaching adolescents about traffic safety, school

teachers and road safety professionals should also emphasize improving their skills. Online platforms, such as the one considered here, can assist adolescents in learning the skills required to navigate traffic scenarios safely.

Regarding the time spent per module per question, most of the time was spent on situation awareness. Conversely, the least time was spent on the knowledge and risk management module, possibly due to the students' excellent knowledge of traffic signs, making it easier for them to complete this part. This observation also suggests that low performance is associated with a higher time investment.

4.2. Difference in Scores at Pre-Measurement Stage

There was no significant difference in the pre-measurement questionnaire administered to both the CG and EG, except for one question related to risk detection and situation awareness, indicating that, in general, both groups were at the same level regarding traffic safety knowledge. Regarding the scores, there is room for improvement, exemplifying the potential of online traffic safety education for adolescents.

4.3. Difference in Scores at Post-Measurement Stage

The post-measurement questionnaire administered after one week revealed that the EG, which completed the platform, performed better than the CG in knowledge, risk detection, and risk management modules. This could be attributed to the detailed feedback provided in the platform, which helped the EG understand different situations and enhance their knowledge and skills in traffic safety. There was no significant difference in situation awareness between the two groups, indicating similar performance in the post-measurement questionnaire.

4.4. Participants Opinions about the Platform

Overall, the adolescents expressed satisfaction with the R2S platform, which increased their awareness of traffic-related issues. More than half of the adolescents from both groups claimed to have good traffic knowledge and skills. However, they faced difficulties when answering situation-based questions. They also suggested making the platform more interactive by incorporating videos and pictures to create scenarios that are realistic and closely related to real-life situations.

5. Limitations and Further Research

It is necessary to mention some limitations of the current study. Firstly, it was impossible to link the adolescents who did the platform and those who filled out the post-measurement questionnaire in the EG, preventing the identification and removal of adolescents who filled out the questionnaire but did not use the platform. Secondly, the study period was at the end of the academic year (exam preparations), and fewer adolescents were available for the platform and the pre-post study. Additionally, the COVID-19 restrictions required students to use the platform at home, limiting their ability to ask any questions they had while using the platform and decreasing the response rate in post-measurement questionnaires (less control, more internet problems). It is suggested that to evaluate this platform further, it is crucial to involve more adolescents (from different cities in Pakistan) to better emphasize the benefits of using the online platform. In addition to this, the opinions of other stakeholders, i.e., parents and teachers, about road safety education platforms should also be investigated to determine their acceptability in the region. Also, long-term testing is necessary to fully understand its impact on adolescents' traffic safety behaviors. This will involve extended follow-up studies to assess retention of traffic knowledge and changes in behavior over time. Also, a longitudinal approach in the future is needed to verify the platform's practical implications. Lastly, the current outcomes already provide insights into how gamified platforms can help participants develop their skills and knowledge regarding traffic safety in Pakistan.

6. Conclusions

This study provides initial insights into the possibilities of an online platform to teach traffic safety to male secondary school adolescents who commute to school on a motorbike in Pakistan. The platform focuses on enhancing traffic knowledge and skills through real-life road scenarios, motivating participants to engage with the platform and improve their understanding and awareness of traffic safety.

Considering that the school education system in Pakistan generally lacks a comprehensive emphasis on traffic safety and road traffic injuries, leading to a higher incidence of accidents among children [52], this study, along with the findings of [67], highlights the merits of educational interventions in increasing traffic safety knowledge among adolescents. Therefore, it is crucial to conduct further research and incorporate traffic safety education into the regular curriculum within the school education system of Pakistan.

Given that this was the first exploratory study conducted in Pakistan, raising awareness among stakeholders and educational institutions about this type of study is important. Involving stakeholders and highlighting the advantages of this online platform in the education sector can be beneficial. By emphasizing the importance of traffic safety through this platform, it can be integrated into students' academic year, enabling them to acquire the knowledge and skills necessary for safe motorcycle riding. These findings can guide researchers and policymakers in Pakistan and other developing countries in addressing adolescent traffic safety concerns.

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Appendix A. Questionnaire Survey

Survey Questions	Options	Supplement with Picture
What is your age?	Open Ended	-
What is your gender?	1. Male 2. Female	-
What is your school name?	Open Ended	-
Which grade are you in?	1. 9th 2. 10th	-
How do you most often go to school?	1. On Foot 2. Motorbike 3. Cycle 4. Others	-

Survey Questions	Options	Supplement with Picture
Do you have a license?	1. Yes 2. No	-
How many times have you been involved in a traffic fine/accident?	1. 1 2. 2 3. More than 2	-
Did you do any offence and not receive any fine?	1. Yes 2. No 3. Maybe	-
How would you rate your traffic knowledge?	1. Very Good 2. Good 3. Neutral 4. Bad 5. Very Bad	-
How would you rate your traffic skills?	1. Very Good 2. Good 3. Neutral 4. Bad 5. Very Bad	-
What do you think when a vehicle can go left?	1. When the signal turns green 2. When the signal turns yellow 3. Turn left without using signal	Yes
While riding a bike, what is the most important thing to do?	1. Drive at left lane of the road 2. Wearing a Helmet 3. Driving at 45 km/h speed on the road	Yes
What do you pay attention to while moving on the road?	-	Yes
You want to overtake the vehicle going in front, what will you do best?	1. You can overtake the in front vehicle from the left side 2. You can overtake the in front vehicle from the right side 3. You can overtake the in front vehicle from any side	Yes
You want to enter the main road, what will you do best?	(1) Look for the traffic which is coming from the left side of the road. (2) Look for the traffic which is coming from the behind and use the indicator to give signals for the other vehicles (3) Look for the vehicles on the main road and quickly enter the main road with other vehicles	Yes
What do you see while driving a motorbike?	1. Cars 2. Truck/Van/Rickshaw 3. Motorcycle 4. Pedestrian 5. Traffic sign 6. Traffic light 7. Zebra crossing 8. Street lights	Yes
What do you understand by this traffic sign?	1. You must give way to all vehicles coming from your right 2. You must give way to all vehicles coming from your left 3. You must give way to all vehicles coming from your behind	Yes
What is the meaning of this traffic sign?	1. There is pedestrian crossing where pedestrian can cross the road 2. Pedestrian can't cross the road due to high traffic 3. Pedestrian can use this footpath for crossing	Yes
You need to listen to a phone call on the road, what will you do?	1. You can listen the call with free hand while driving a bike 2. Stop the bike on the right side of the road and listen the call 3. Stop the bike on the left side of the road and listen the call	Yes
You want to go right at an intersection, what will you do?	1. Switch the lane to right by showing an indicator and turn to right by seeing left and right 2. Switch the lane to right quickly when the traffic is slow and turn to right 3. Turn to right without showing an indicator and looking left and right	Yes

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