Implementation of a gamified e-learning platform focusing on traffic knowledge and skills among Vietnamese adolescents

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Abstract

Adolescents are considered as vulnerable road users and education is one way to increase their traffic knowledge and riding skills. In this study, a version of an e-learning platform tailored to the Vietnamese context is used to improve four specific competences, i.e. traffic-related knowledge, situation awareness, risk detection, and risk management. Images and short videos from authentic traffic situations are used as learning stimuli and users have the possibility to self-test their competences via a separate "finale". Gamification elements (i.e., points, levels, badges and cups) are incorporated into the platform to encourage user engagement. The purpose of this study is to conduct a pilot study using a gamified e-learning platform, and to assess user experience. 47 adolescents (aged 15-16) participated in a single arm (i.e., test group only) within-subject design with baseline and post-measurement. Results indicate that scores on the post-measurement were statistically significantly higher as compared to baseline performance. Scores were better for the risk management module. There were no statistically significantly different in scores between familiar situations (i.e., coming from the city where participants are living) and unfamiliar situations. Males overall performed better than females. Results for user experience are also discussed.

Keywords: adolescent riders, e-learning platform, gamification, traffic knowledge and skills.

1. Introduction

Traffic crashes are considered as one of the most alarming problems in the world, especially in developing countries like Vietnam. The World Health Organization demonstrates that traffic crashes occur mostly among young people between the age of 15 to 29 in Vietnam (World Health Organization [WHO], 2015). Adolescent-related traffic crashes account for more than 90% of all traffic crashes involving minors (Vu & Nguyen, 2017). Important in this regard is that adolescents typically transition to independent operation of motorized/electrified vehicles for their daily travelling. Different reasons have been forwarded to explain this increased crash risk among adolescents, ranging from disregard of traffic laws, lack of knowledge about traffic rules and code (McDonald et al., 2014), insufficient hazard awareness, and underdeveloped higher-order driving skills (Mayhew, 2007). In safety-critical situations, adolescents often have difficulty in timely detecting and appropriately responding to imminent hazards (Sagberg & Bjørnskau, 2006). A study by Vidotto et al. (2011) also found that ignorance of traffic laws, low traffic safety awareness, and poor riding abilities are primary factors contributing to the rise in road accidents among adolescents. Therefore, improving safety-related knowledge and skills is essential for the reduction of crash risk among adolescent road users.

In Vietnam, a variety of countermeasures have been implemented to improve road safety, such as increased social marketing efforts, dissemination of traffic rules and code on mass media, and increased fines for traffic violations (Khuat & Huyen, 2011). However, most of the interventions do not reach the targeted objectives because most of them only focus on consciousness raising, leaving unaddressed important safety-related determinants such as improving traffic knowledge and riding skills. In early 2017, the President of the People's Committee of Ho Chi Minh City asked district departments to review and analyse the causes of traffic crashes in order to develop effective solutions, especially focusing on the prevention of speeding and on improving the education of traffic safety rules. In addition, the National Traffic Safety Committee issued an action plan for the year of traffic safety 2018 focussing more particularly on the theme "Traffic safety for children" with the underlying goal to promote the idea that "Human life is above all". This action plan emphasized the application of information technology to improve the efficiency of traffic safety education in schools. That being said, it remains a fact that traffic safety education is still no compulsory part of the official school program in Vietnam. Instead, traffic safety lessons are integrated into other subjects like natural and social sciences (at the primary level) and citizen education (at the secondary and high school levels). Traffic safety education is also incorporated into extracurricular activities such as the National Traffic Safety Month school event, which is held in September at the high school and university levels (United Nations, 2018) or the "Safety for me, for you and for all" program which was implemented by the Global Road Safety Partnership in a selection of primary schools in Hanoi, Danang, and Ho Chi Minh City (GRSP, 2017). However, no formal evaluation has been performed to investigate the effectiveness of these programs.

1.1 Traffic safety education

In Vietnam, education is a top priority for policy makers, as can be derived from Article 35 of the current constitution. More specifically related to road safety, the basic educative strategy for adolescents is to "develop an ability to predict risks and have safe travel habits" (Ministry of Transport of Vietnam, 2010). This means that adolescents should be able to timely detect and recognize risks in traffic and manage them adequately. Traffic safety education for adolescents is intended to teach the necessary knowledge and skills for two-wheeled riders, and tailoring these to their psychological development and local requirements. In addition, it aims to improve adolescents' attitudes and abilities in order to be well prepared for potential hazards on the road. Although the actual effectiveness of (driver) education programs remains a debated topic in the literature (e.g., Akbari et al., 2021; Glendon et al., 2014; Ker et al., 2005; Mayhew et al., 1998; O'Neill, 2020), recent research is not calling for an abandonment of road safety education, but advocates developers of educative programs for the improvement of road safety to base interventions as much as possible on the science of behavioural change and to conduct the necessary evaluations in order to uncover what works and what doesn't (e.g., Box & Dorn, 2023). Moreover, there are studies available, indicating that lack of traffic safety education can negatively impact road users' behaviour which in turn might result in increased crash risk (e.g., Meyer et al., 2014). A study by Shell et al. (2015) conducted among 151,880 teens in the United States found that rates of traffic- and alcohol-related violations were lower among adolescents who had completed a driver education program with attention for traffic laws and regulations, and for the implications of safe/risky driving. In another study focusing on how much driver education programs affect student outcomes (i.e., enhancements in knowledge, attitudes, and safer

behaviours) and how this in turn impacts the number of traffic crashes, Mayhew et al. (2014) came to the conclusion that driver education is a meaningful strategy for lowering traffic accidents, particularly those that result in injury or death for adolescents. Consequently, improving traffic knowledge and reducing risky riding behaviour can be seen as important targets for traffic educative interventions.

The design of educational tools would be useful for promoting not only the avoidance of risky behaviours, but also a generalized awareness of road safety issues (Useche et al., 2019). The effectiveness of educational programs is not always evaluated (Ben-Bassat & Avnieli, 2016), but studies that evaluated different programs showed success in promoting (awareness of) road safety (Cuenen et al., 2016; Floreskul et al., 2016; Glendon et al., 2014; Lund & Rundmo, 2009; Markl, 2016; Twisk et al., 2014). There are several components that affect the success of educational programs. The first component is participation of people who are in the nearby social vicinity of adolescents such as their parents or relatives (Yeh et al., 2008). Schwebel et al. (2012) for instance, found that parents' involvement contributes to a behavioural change in their children. The second component is program dose. The more intensive and prolonged the program, the more effective it is (Zeedyk & Wallace, 2003). A third component is program compatibility with the background profile of participants. Traffic participants can be divided into different groups according to their age, abilities and understanding. In order for a program to maximize its efficiency, the content given must be tailored to the specificities of the targeted group. For example, programs for children or adolescents should focus more on dynamic content with colourful and attractive images and videos instead of 'dry' lectures with text only (Schwebel et al., 2012).

Much research has been done on the development and training of hazard perception skills. Petzoldt et al. (2013) found that hazard perception training effectively contributes to reconstruction and improvement of brain processes that help to improve driver performance. Drivers trained by this program were involved in less road crashes than those who were not trained by it (Haworth & Mulvihill, 2006; Sagberg & Bjørnskau, 2006). Training hazard perception skills by means of computerized tools appears in many road safety studies (Casutt et al., 2014). In terms of safety, Mayhew has demonstrated that computerized practice of hazard perception can help drivers achieve safety goals (Mayhew, 2007). Petzoldt et al. (2013) compared computerized practice to traditional training activities through books and lecture-based learning to prove its effectiveness in improving hazard perception skills. Computers that provide dynamic visual contents (real-life video footage or computerized animation) make traffic situations more vivid and realistic than static images in books. A major advantage of computerized practice is the flexibility to adapt to the needs of the students: question difficulty that is adjusted to different subjects and situations, repetition of incorrectly answered questions, provision of feedback depending on the answer. Rosenbloom et al. (2015) also used computerized software to create a hazard perception test with inclusion of various typical road situations that trainees had to cope with this study.

In today's world of advanced science and technology, e-learning platforms are considered effective alternatives to traditional learning methods. By using e-learning systems, the user's learning motivation can be boosted by flexible learning accessibility and the simplicity of information sharing (Robson et al., 2015). Flexibility in how participants can learn at any time and from any location is another reason for using e-learning systems (Liaw & Huang, 2013; Ramayah & Lee, 2012). E-learning platforms have been widely used in the education sector to support traditional learning in different areas such as providing out-of-school children alternative learning opportunities (Stubbé et al., 2016), promoting healthy eating habits (Henderson & Alexander, 2012), and lessening the effects of diabetes on children (Al-Mansoori et al., 2011). However, there are not many studies on the use of e-learning in the field of traffic safety. In a study by Rakoczi et al. (2013) an e-learning course was designed to record various eye movement metrics during the visual perception of international traffic signs, with the purpose of familiarizing leraners with foreign signage. While sign origin and ethnicity had some effects on gaze, training materials generally did not affect eye movement metrics or task success rates. The study also produced some intriguing findings that improved the usability of the e-learning environment and the design of the learning process. These could aid in enhancing the user interface of the e-learning platform and creating more aesthetically appealing e-learning assignments. This study may help driving education programs improve students' understanding of traffic signs, which could lead to greater awareness and driving safety. To the best of our knowledge to date, Route2school (detailed in section 1.3) is considered the only e-learning platform that integrates gamification elements focusing on traffic knowledge and skills.

1.2 Gamification

Gamification is a fast expanding trend that is described as the usage of game design principles outside the context of entertainment (Deterding et al., 2011). The objective of gamification is to increase people's motivation and help them achieve their personal goals (Lopez & Tucker, 2019). Gamification is a growing phenomenon in education due to its effect on student learning (da Rocha Seixas et al., 2016). Gamification mechanisms have been incorporated into online learning and improved learning outcomes and boosted engagement with digital platforms (Akrolu et al., 2017). Gamification features can be of various kinds including points, badges and profile updates (Gafni et al., 2018), leaderboards, meaningful stories, avatars and teammates (Sailer et al., 2017), achievements, feedback, clear goals and a narrative storyline (Hamari et al., 2014). Gamification allows student self-determine their learning paths (Nistor & Iacob, 2018) and motivates individuals to start or maintain goal-oriented behaviour (Sailer et al., 2017). Additionally, it is a teaching strategy to enhance instruction, empower students, boost their participation and interaction, and inspire them to develop their skills (Zainuddin et al., 2020). According to Ding (2019), gamification elements in the learning process assist students to become more goal-oriented through more perseverance, repetition, teamwork, and amusing competition with others. By utilizing game design elements (i.e., points, levels, badges, and leaderboards), gamification attempts to promote not only gradual mastery of different competences (in this case, improving traffic knowledge and skills), but also intrinsic motivation to change unfavourable opinions, attitudes, and behaviours related to traffic safety (Hamari & Koivisto, 2015).

1.3 The Route2school platform

This study will focus on the implementation of the Route2school e-learning platform developed by the Transportation Research Institute (IMOB - https://www.uhasselt.be/en/instituten-en/transportation-research-institute-imob) of Hasselt University, Belgium. Route2School (R2S) is an innovative e-learning platform (Figure 1) meant to improve traffic understanding of participants so that they can deal better with traffic situations. Users will not only learn about the overall traffic context, but be exposed as well to real traffic situations. For this study, a version specifically tailored to the Vietnamese context was developed. The platform includes multiple choice questions, hotspot questions and questions using 360-degree images. This platform has already been implemented in several countries (i.e., Belgium, Indonesia and Vietnam) with changes in learning content to suit different target groups. For example, the original version of the R2S platform was targeting primary school children aged 9 to 13 (Riaz et al., 2019), while the Indonesian version was used for primary and junior high school students aged 9 to 16 (Putri, 2020; Sitohang, 2022). The version developed in Vietnam was aimed at high school students aged 15-18 (Pham, 2019).

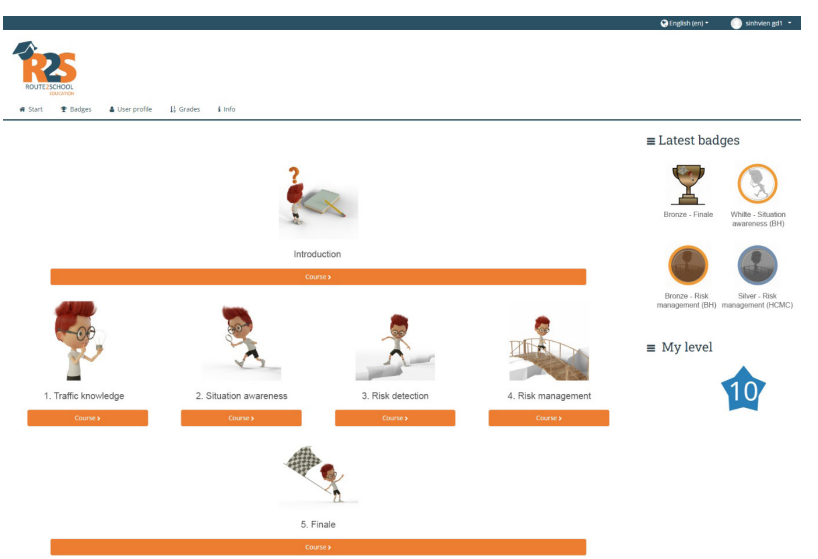

Figure 1 The home page of the R2S platform.

More in detail, the R2S platform consists of five modules with four main modules (i.e., traffic knowledge, situation awareness, risk detection and risk management) and the fifth module offering the opportunity to users to test their acquired competences (i.e., the "finale"). In the traffic knowledge module, participants learn more about the traffic rules and code. The situation awareness module is meant to stimulate participants' sensitivity to contextual factors in order to improve their prospective abilities of how a certain situation will further develop. In the risk detection and risk management module, participants learn how to spot, recognize, and respond to imminent hazards. The fifth module ("finale") consists of a mix of exercises and questions from the four main modules. To create diversity in learning materials screenshots and video footage from both familiar and unfamiliar situations (i.e., from other cities) are included. All exercises and questions are accompanied by feedback that is meant to provide deeper insight into why a certain answer is correct or incorrect.

The R2S platform consists of gamification aspects including points, levels, badges, and cups (Figure 2). You begin your learning at level 1 and you reach level 10 once you have finished all the modules. Badges serve as digital awards for accomplishments. You can win a badge per module. The shape of the badge depends on the module type you have finished, and the colour of the badge is dependent on the scores you have earned. You can earn a badge in the shape of a cup when you have finished the final module. Moreover, the character Charlie in each question makes the questions more vivid for the participants.

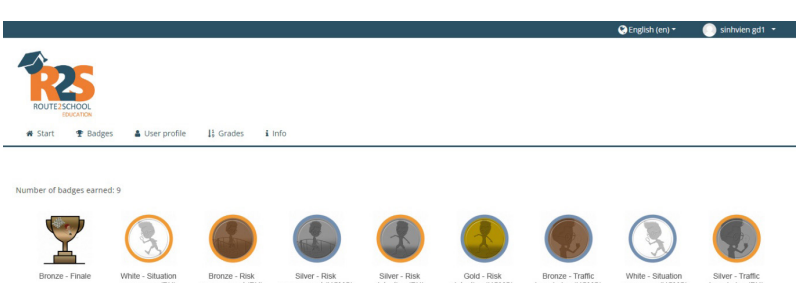

Figure 2 Gamification features of the R2S platform.

2. Objectives and research questions

This study aims to (1) implement a gamified e-learning platform (see section 1.2) meant to focus on safety-related knowledge and skills of Vietnamese adolescents and (2) to assess user experience. Like in the study by Riaz et al. (2019) where the R2S platform was offered to Belgian children age 9-13, the following research questions will be addressed:

- Research question 1: Is there a statistically significant increase in scores from baseline measurement to post-measurement?
- Research question 2: Is there a statistically significant difference in scores across the different modules offered by the platform?
- Research question 3: Is there a statistically significant difference in scores comparing familiar situations (i.e., based on the city where participants live) with unfamiliar situations?
- Research question 4: Is there a statistically significant difference in scores comparing males with females?
- Research question 5: Which exercises/ questions do participants find most difficult?
- Research question 6: How did participants experience using the e-learning platform?

3. Methodology

3.1 Study design, sampling and recruitment

This study adopted a single arm (i.e., test group only) within-subject design with baseline and post-measurement, and was part of larger research project for which ethical approval was obtained at the Social and Societal Ethics Committee of Hasselt University: reference REC/SMEC/VRAI/190/ 123. More specifically, participants had

five weeks to complete the five modules offered by the R2S platform, where first attempt scores for the four main modules (i.e., traffic-related knowledge, situation awareness, risk detection, and risk management) served as baseline measure, and performance on the fifth module ("finale") served as post-measure. In addition to platform data (targeting outcome evaluation), participants received a paper-pencil questionnaire at the end of the experiment. The first part of this questionnaire probed for personal characteristics (i.e., gender, age), traveling characteristics (i.e., vehicles usually used, self-riding experience), and past experience with the use of e-learning tools. The second part focused on several aspects of user experience (i.e., process evaluation) such as easiness of use, perceived relevance, satisfaction, et cetera. Gamification elements (i.e., points, levels, badges and cups) are considered as one of the factors affecting user experience. In total, this part contained 17 items on a 5-point Likert-scale ranging from 1 (totally disagree) to 5 (totally agree).

A convenience sampling approach was adopted with voluntary participation after informed consent and confidential and anonymous data treatment.
The primary target group were high-school students (aged 15-16) in Ho Chi Minh City. First, the research team approached the administration of a high school in Ho Chi Minh City. After presenting the purpose as well as basic information related to the research, the administrators agreed to allow the application of the R2S program to students of two grade 10 classes. The research team had direct contact with the students through the support of form teachers. In total, 69 participants subscribed to the program of which 60 completed at least half of the program, and 47 completing all modules (for demographic composition of the sample investigated, see Table 1 below). Overall, gender distribution was quite balanced. Nearly 80% of participants rode their own motorcycle from home to school. Strikingly, almost 60% of participants rode motorcycles over 50 cubic centimetres. One of the concerns noted for this study is that there are a lot of participants who are not old enough to ride motorcycle over 50cc. In fact, riding motorcycle over 50cc is only allowed for Vietnamese citizens over 18 years old with a legal riding license, according to Vietnamese law on traffic safety. The majority of participants in the program had a riding experience of less than three years with around 68% actively riding for less than one year. More than 80% had never used an e-learning platform before.

Table 1. Demographic sample composition

	Frequency (N=47)	Percent (%)
Gender		
Male	22	46.8
female	25	53.2
Vehicle usually used		
Bicycle	6	12.8
E-bicycle	4	8.5
Motorcycle<50cc	9	19.1
Motorcycle>50cc	28	59.6
Self-riding experience		
Under 1 year	32	68.1
1 to 3 years	12	25.5
Over 3 years	3	6.4
Learnt a road safety e-learning before		
Yes	6	12.8
No	41	87.2

3.2 Data collection protocol

Data was collected during the first trimester (i.e., September - December) of the 2020-2021 school year. All personal data of participants were anonymized and stored in the private computer of a research member. The following implementation protocol was followed: before actually using the R2S platform, participants received a short demo-presentation about the R2S platform. Participants registered and created accounts at school while working in computer classes. As most participants were familiar with using computers, no significant problems in creating an account were encountered. Afterwards, participants received a deadline of five weeks to complete all modules, and they were instructed to contact the research team (via mobile phone) in case they encountered problems. Form teachers also participated in the pilot test, acting as monitors of the participants' progress and scores. At the end of the five-week period, the paper-and-pencil questionnaire focussing on background characteristics and user experience was administered. This was done in class. Form teachers collected participants' fully completed questionnaires and sent these back to the research team.

Table 2. Mean values of the baseline and post measurement

Module	Mean scores (SD)		
	Baseline measurement	Post measurement	Change
Traffic knowledge	63.40 (15.22)	74.47 (20.30)	+11.07***
Situation awareness	42.13 (27.74)	67.66 (24.87)	+25.53***
Risk detection	65.11 (23.02)	74.47 (18.04)	+9.36**
Risk Management	69.79 (28.85)	75.74 (23.57)	+5.95
Total	60.11 (16.60)	73.09 (14.24)	+12.98***

* $p < .05$; ** $p < .01$, *** $p < .001$

3.3.Data analysis

Data were analysed using SPSS (IBM Statistics version 24). Paired-sample t-test was used to compare results of the baseline measurement with results of the post-measurement. Repeated measure ANOVA was use to investigate difference in scores across the different modules offered by the platform and between familiar situations with unfamiliar situations. One-way ANOVA was used to examine whether scores on the four main modules and scores on situation familiarity (familiar vs. unfamiliar) were statistically significantly different in function of gender (male vs. female). All statistical tests adopted an Alpha level of .05. For that part of the questionnaire probing for user experience, descriptive statistics were calculated.

4. Results

4.1 Research question 1: Is there a statistically significant increase in scores from baseline measurement to post-measurement?

The "finale" module consisted of 20 questions randomly drawn from the four main modules. As shown in Table 2, in each module, mean scores for the post-measurement were higher than those of the baseline measurement. Changes in scores were largest for the situation awareness module (+25.53, $p < .001$), followed by the traffic knowledge module (+11.07, $p < .001$), and the risk detection module (+9.36, $p < .01$). Contrary to what was found for the other modules, the change in scores for the risk management module was not statistically significantly different change is not significant ($p > .05$).

4.2 Research question 2: Is there a statistically significant difference in scores across the different modules offered by the platform?

There were significant differences among the modules in mean scores ($F(3) = 19.235$, $p < .001$). Table 3 shows that among the five modules in the R2S platform, scores (ranging from 0-100) were highest for the risk management module (mean = 72.77 and SD = 18.90) followed in decreasing order by the risk detection module (mean = 68.40 and SD = 17.07), the traffic knowledge module (mean = 61.60 and SD = 11.98), and lowest scores for the situation awareness module (mean = 52.34 and SD = 21.16).

4.3 Research question 3: Is there a statistically significant difference in scores comparing familiar situations (i.e. based on the city where participants live) with unfamiliar situations?

As shown in Table 3, higher scores were recorded for familiar situations in each of the four modules. However, there was not a statistically significant difference in scores comparing familiar situations with unfamiliar situations ($F(1) = 1.319$, $p > .05$).

4.4 Research question 4: Research question 4: Is there a statistically significant difference in scores comparing males with females?

The score change of males was higher than that of females in most modules except for the risk detection module where the score increment of males was only +6.36 while that of females was +12.00. However, there was not significantly significant gender difference in score increment between the baseline and post measurements (Table 4).

Table 5-8 shows detailed statistical information about the performance results achieved by gender difference. Except for the results recorded in the traffic knowledge module, males tend to perform better than females through scores in most modules. In the traffic knowledge module, the mean score of females in familiar situations was 65.20 (SD = 16.10) and that of males was 60.45 (SD = 14.95), while there is not much difference between males and females in unfamiliar situations (mean = 60.00 (SD = 13.80) and mean = 60.40 (SD = 13.38), respectively). The largest difference in scores between males and females was highlighted in the situation awareness module, where the mean score of males was 60.45 (SD = 19.75) and that of females was 45.20 (SD = 20.08).

Table 3. Mean scores and standard deviations (SD) of participants for the five modules

Modules	Mean scores (SD)		
	Total	Familiar situations only	Unfamiliar situations only
Traffic knowledge	61.60 (11.98)	62.98 (15.59)	60.21 (13.43)
Situation awareness	52.34 (21.16)	53.62 (24.09)	51.06 (25.22)
Risk detection	68.40 (17.07)	69.36 (21.61)	67.45 (18.11)
Risk management	72.77 (18.90)	73.83 (21.52)	71.70 (19.71)
Finale	73.09 (14.24)		

Table 4. Gender difference in score increment from baseline measurement to post-measurement

	Traffic knowledge		Situation awareness		Risk detection		Risk management		Finale	
Gender	Score change	F	Score change	F	Score change	F	Score change	F	Score change	F
Male	+15.45	2.518	+30.91	1.340	+6.36	0.737	+8.18	0.306	+15.23	1.873
Female	+7.20		+20.80		+12.00		+4.00		+11.00	

** p < .05; ** p < .01, *** p < .001*

Table 5. Mean scores and standard deviations (SD) for male and female participants for the five modules

Gender	Modules	Mean scores (SD)		
		Total	Familiar situations only	Unfamiliar situations only
Male	Traffic knowledge	60.23 (12.10)	60.45 (14.95)	60.00 (13.80)
	Situation awareness	60.45 (19.75)	62.27 (21.59)	58.64 (23.96)
	Risk detection	73.64 (15.05)	75.91 (17.09)	71.36 (19.83)
	Risk Management	76.82 (19.00)	77.27 (22.29)	76.36 (20.60)
	Finale	80.45 (10.46)		
Female	Traffic knowledge	62.80 (12.00)	65.20 (16.10)	60.40 (13.38)
	Situation awareness	45.20 (20.08)	46.00 (23.98)	44.40 (24.85)
	Risk detection	63.80 (17.69)	63.60 (23.78)	64.00 (16.07)
	Risk Management	69.20 (18.47)	70.80 (20.80)	67.60 (18.32)
	Finale	66.60 (14.12)		

Table 6. Gender difference in scores across the different modules

	Traffic knowledge		Situation awareness		Risk detection		Risk management		Finale	
Gender	Mean scores (SD)	F	Mean scores (SD)	F	Mean scores (SD)	F	Mean scores (SD)	F	Mean scores (SD)	F
Male	60.23 (12.10)	.534	60.45 (19.75)	6.857*	73.64 (15.05)	4.151*	76.82 (19.00)	1.939	80.45 (10.46)	3.370***
Female	62.80 (12.00)		45.20 (20.08)		63.80 (17.69)		69.20 (18.47)		66.60 (14.12)	

** p < .05; ** p < .01, *** p < .001*

In Table 6, scores for the traffic knowledge module ($F = .534$, $p > .05$) and the risk management module ($F = 1.939$, $p > .05$), were not statistically significantly different in function of gender. Different from that significant differences between genders were found for the situation awareness module ($F = 6.857$, $p < .05$), the risk detection module ($F = 4.151$, $p < .05$), and the finale module ($F = 3.370$, $p < .001$). No statistically significant gender differences (shown in Table 7) were found for scores on both familiar situations ($F = 3.512$, $p > .05$) and unfamiliar situations ($F = 3.370$, $p > .05$).

There was a significant gender difference in answering difficult questions ($F = 8.762$, $p > .05$). Males performed better than females in answering difficult questions (see Table 8). While the mean score for males was 41.74 (SD = 20.36), that of females was only 26.18 (SD = 15.60).

4.5 Research question 5: Which exercises/ questions do participants find most difficult?

Difficult questions are questions where less than 50% of participants gave a correct answer at the baseline measurement (shown in Table 9). While the risk management module has no questions that are considered difficult, difficult questions are spread out evenly in the other three modules.

Table 7. Gender difference in scores between familiar and unfamiliar situations

	Familiar situations		Unfamiliar situations	
Gender	Mean scores (SD)	F	Mean scores (SD)	F
Male	69.00 (11.00)	3.512	66.59 (14.93)	3.370
Female	61.40 (15.93)		59.10 (13.05)	

** p < .05; ** p < .01, *** p < .001*

Table 8. Gender difference in score among difficult questions

		95% Confidence Interval for Mean			
Gender	Mean score (SD)	Lower Bound	Upper Bound	Levene Statistic	F
Male	41.74 (20.36)	32.71	50.76	3.861	8.762**
Female	26.18 (15.60)	19.74	32.62		

*** p < .01*

Table 9. Proportion of students giving correct answers for each question

Question	Proportion of students giving correct answers (%)							
	Traffic Knowledge		Situation Awareness		Risk Detection		Risk Management	
	Familiar situation	Unfamiliar situation	Familiar situation	Unfamiliar situation	Familiar situation	Unfamiliar situation	Familiar situation	Unfamiliar situation
1	51.1	89.4	55.3	51.1	48.9	80.9	74.5	74.5
2	57.4	51.1	31.9	21.3	44.7	89.4	63.8	78.7
3	70.2	19.1	51.1	57.4	61.7	93.6	57.4	93.6
4	76.6	76.6	63.8	63.8	85.1	38.3	63.8	89.4
5	57.4	51.1	29.8	55.3	80.9	68.1	76.6	91.5
6	55.3	31.9	57.4	29.8	85.1	57.4	91.5	61.7
7	40.4	74.5	74.5	55.3	74.5	74.5	85.1	53.2
8	44.7	53.2	61.7	55.3	66.0	57.4	76.6	59.6
9	85.1	74.5	59.6	66.0	61.7	48.9	74.5	53.2
10	91.5	80.9	51.1	55.3	85.1	66.0	74.5	61.7

4.6 Research question 6: How did participants experience the use of the e-learning platform?

Figure 3 displays the proportion distribution of answers to each statement. In the aspect of technological dimensions (i.e., 'you can find the R2S platform website easily', 'the R2S platform is easy to use', 'the R2S platform runs smoothly'), approximately 65% of participants supposed that they could find the R2S platform website easily and the R2S platform was easy to use. However, nearly 60% of participants did not agree with the statement that the platform runs smoothly. Among three statements about interface design dimensions, 75% of participants liked the quality of images and videos. Remarkably, participants tended to be neutral about the interface design of the R2S platform. There were five statements about the content dimensions of the R2S platform including 'the difficulty of the questions is appropriate to you', 'your-own-city questions attract you', 'questions using 360-degree images are interesting', 'feedback is useful' and 'the finale module is necessary'. The participants generally expressed positive agreements towards the contents of the R2S platform. Interestingly, nearly 80% of participants agreed with the statement that feedback was useful. More than 50% of participants indicated that they can control their time in learning with the platform. With the statement "you like points, levels, badges and cups after finishing modules", a neutral result was given by participants. Nearly 60% of participants were satisfied with the R2S platform. More than 70% of participants agreed that they would continue to use the R2S platform and nearly 65% of participants supposed that they would recommend the R2S platform to others. In summary, after using the R2S platform, users gave very positive feedback on the content aspect and neutral opinions about the interface design and gamification elements. Although there are a few negative opinions regarding the technical functionality, overall users are satisfied with the R2S platform. Furthermore, they believe they will continue to use the R2S platform and recommend it to others.

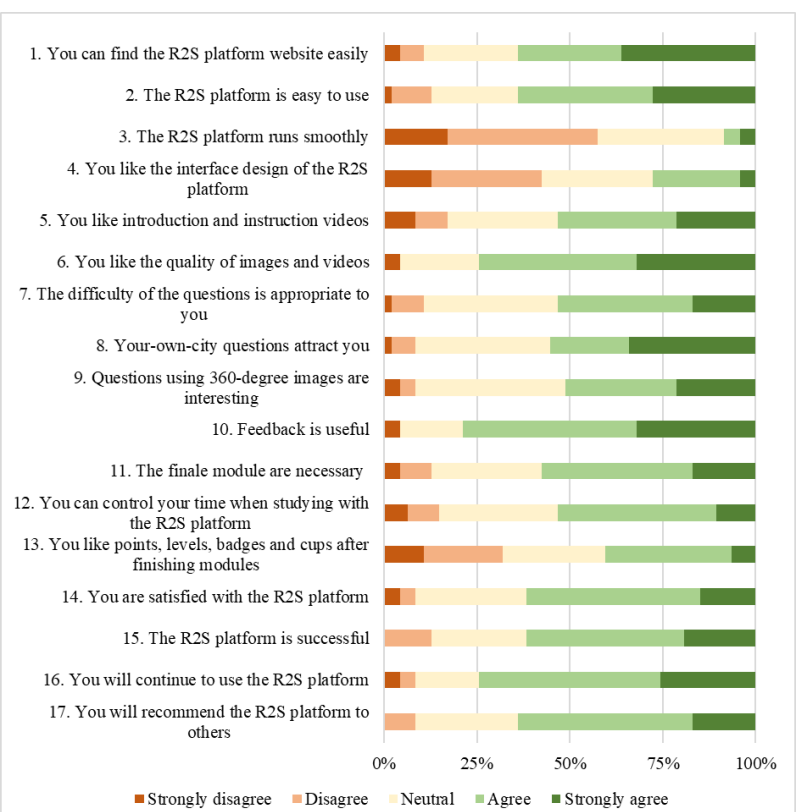

Figure 3 Score proportion of the R2S platform evaluation.

5. Discussion

The aim of this study is to investigate the effectiveness and user experience of an e-learning platform meant to improve safety-related knowledge and skills of Vietnamese adolescent riders. In comparison to scores in the baseline measurement, the score increment in the post-measurement highlighted the significant effects of the platform in improving the traffic safety knowledge and skills of adolescents, especially when dealing with the real traffic scenarios presented in the program (research question 1). Many participants could give the correct answer in the post-

measurement after giving the wrong answer in the baseline measurement. This shows that giving results and explaining answers right after each question has an outstanding advantage in improving participants' knowledge and skills in traffic, or at least helping participants to learn and remember the rules and traffic situations outlined in the platform. In fact, feedback has proven to be helpful and to help to answer related questions better (Krause et al., 2009, Vasilyeva et al., 2008).

When comparing results among modules, the lowest scores were recorded for the situation awareness module, which proves that participants have a lot of trouble in scanning traffic environments (research question 2). Situation awareness refers to a person's perception and understanding of their dynamic environment (Wright et al., 2004). From a road user perspective, this knowledge encompasses the relationships between road user goals and behaviours, vehicles, the road environment and infrastructure (Salmon et al., 2013). While road environment factors such as road maintenance and design issues featured strongly as secondary contributors to traffic crashes (Allen et al., 2017), novice or inexperienced riders often have weak scan traffic environments (Liu et al., 2009) or even underestimate certain traffic hazards (Brown & Groeger, 2007) which significantly contribute to slow response to hazards.

There was not a statistically significant difference in scores comparing familiar situations with unfamiliar situations (research question 3). The finding can be explained that the other city used in this study has a traffic context quite similar to the city where participants live. This result is not consistent with the study of Riaz et al. (2019), who applied the R2S platform to 44 primary school pupils in Belgium and found that participants got higher scores in familiar situations than in unfamiliar situations.

Another aspect to be noted is that the difference between males and females in performance results in most of the modules. The results presented that males often showed better performance than females in all modules of the platform (research question 4). Most especially, there is a rather large gap in scores between males and females in the situation awareness module when the mean score of males is significantly higher than that of females (60.45 and 45.20, respectively). This is similar to the results demonstrated in many previous studies. In fact, by using two measurements of situation awareness, the study of Dong (2018) presented that males were more confident than females when answering situation awareness questions. In addition, males also have a stronger expression of positive perception of e-learning than females (Ong & Lai, 2006).

Difficult questions are questions in which less than 50% of participants give the correct answer. While the risk management module has no questions that are considered difficult, difficult questions are spread out evenly in the other three modules (research question 5). For the traffic knowledge module, there are quite a few participants who update new information when there is a change in traffic laws. For example, the fine for 'going red light' violations is only 100,000 - 200,000 under the old law and the fine amount at present is 600,000 - 1,000,000 (according to Decree No. 100/2019). For the situation awareness module, questions using 360-degree images cause a lot of difficulties for participants to give correct answers. For the risk detection module, the difficult questions are often those with more than one hazard, and that is difficult for participants to choose which is the most potential hazard being able to lead to a traffic crash. The following studies need to focus more on situations with multiple threats at a time to give participants more experiences to improve their ability to handle situations when encountering similar external situations. This is especially meaningful for complex transport environments like Ho Chi Minh city.

To answer research question 6, an evaluation questionnaire about the R2S platform was created in the aspect of technologies, learning contents, interface designs and satisfaction. Overall, the participants were satisfied with the R2S platform and pledged that they will continue to use the R2S platform and recommend the R2S platform to others. From a technical perspective, it appears the R2S platform performs well in terms of ease of access and use, but that further improvement in terms of operational speed is recommended. Controlling the size of raw data (i.e., images and short videos about real traffic situations) before converting into learning data into the platform is necessary to avoid slow loading of questions during the learning process. Moreover, the potentially negative impact of unstable network quality on users' learning experience should be further explored. A major contribution to satisfaction of participants is credited to the learning contents of the R2S platform. The content aspect, especially feedback for each answer, has brought a certain usefulness when learning with the R2S e-learning platform. The neutral opinion towards the platform's gamification features suggests that further development

of gamification elements is needed to become more effective in engaging adolescents' learning with the R2S platform.

Traffic safety education should be included in a process of lifelong learning and be implemented as a continuous learning process, from kindergarten onwards already. Assailly (2017) for example, stated that if traffic safety education is part of a lifelong learning process, and if it transfers not only knowledge but also "life-skills" (or psycho-social competencies), then it may be beneficial for road safety. Education-based initiatives are a necessity to have a comprehensive and all-encompassing approach to traffic safety. With this goal in mind, the use of the R2S e-learning platform becomes even more meaningful with its innovative features such as encouragement of learner participation through gamification elements, flexibility in learning in terms of time and place, and tailoring of content to profile and context of different target groups. In the current context in Vietnam, in addition to the average duration of the extracurricular program on traffic safety, about 1-2 sessions/semester, the content on traffic safety is mainly integrated into subjects such as natural and social sciences (at the primary level) and Good Citizen Education (at the secondary and high school levels), with a duration of 2 hours/semester (United Nations, 2018). This is not enough for children's long-term and lifelong educational goals towards traffic safety. Therefore, the R2S platform, combined with gamification elements that boost motivation and engagement, can be an effective support tool for building such lifelong learning. In Vietnam, a variety of countermeasures have been implemented to improve traffic safety, such as increased social marketing efforts, dissemination of traffic rules and regulations on mass media, and increased fines for traffic violations (Khuat & Huyen, 2011). However, most of the interventions are not highly effective since they only focus on raising awareness instead of increasing traffic knowledge and riding skills. Because of this, the R2S platform can effectively support a wide range of existing traffic safety solutions. Moreover, education can positively stimulate public acceptance towards road safety measures (Khuat & Huyen, 2011). Interestingly, through the learning results, the R2S platform can help to assess in detail the current traffic safety issues of different target groups (in this study, high school students aged 15-18). This helps to guide solutions and propose more effective policies for improving traffic safety for each specific target group.

6. Limitation and future research

There are some limitations to this study. Firstly, the sample size (N = 47) was small, although this study was meant as a first pilot test. A larger-scale clustered randomized trial with test and control group and pre-post measurement has been conducted as a follow-up to this study, and the results of this outcome evaluation will be reported later. Secondly, for many objective reasons related to participant acceptance and the busy school schedule, this research was only accessible to 15-16-year-old participants. Future research should be expanded to a variety of age groups to have a better overview of the effectiveness of the platform. Finally, program implementation time should also be considered for future research. In the current study, participants had one month from start to finish, but participants were allowed to access the platform whenever they wanted instead of being allowed to do modules weekly. This also made it difficult to assess the frequency of program participation and the extent to which participants' knowledge and skills improve over time. Future research should include a control group to evaluate further the effectiveness of the platform with distinctive features such as gamification and feedback. The immediate and long-term effectiveness of the platform on safety-related knowledge and skills should be developed in future research using a pre-post approach. However, despite the above limitations, the study results presented the potential of the platform in improving traffic safety-related knowledge and skills.

7. Conclusion

This study aims to implement the R2S e-learning platform focusing on traffic safety for adolescents in Vietnam. This study can be seen as the first study to investigate the potential of traffic e-learning in Vietnam. With a combination of outstanding features including gamification, educational technologies, and realistic learning materials, the platform is expected to significantly improve traffic safety for adolescents who are considered vulnerable road users in Vietnam. The results presented that participants significantly increased their scores in post-measurement. Participants performed better results in the risk management module than in other modules. There was not a statistically significant difference in scores comparing familiar situations with unfamiliar situations. Male participants performed better than female participants. Questions related to updated traffic rules or using 360-degree images or situations with multi-hazards caused difficulties for participants.

However, participants generally gave a satisfactory rating and expressed their intention to continue using the R2S platform. This demonstrates the potential advantages of the R2S platform in the field of traffic safety education. These findings may guide future research in traffic safety education for adolescents.

Declaration of interest statement

The authors declare that there is no conflict of financial interests that could have appeared to influence this paper.

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