

## MODERN ROAD SAFETY TRAINING USING GAME-BASED TOOLS

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**Abstract.** In this article we present a web-based e-book used in educational context for teaching road safety to first grade students. The tool is a collection of situations that are presented in a game-based form. The players solve each situation in order to receive points. At the end of the course there is a final evaluation based on the training gaming situations. We use Unity game engine and WebGL for the development of the educational tool. In addition, the tool is cross-compiled for android mobile devices. We evaluate the learning effectiveness of the web-based tool via the t-test, analyze the results and draw conclusions.

**Keywords:** road safety education; serious games; game-based learning; e-learning

### 1. Introduction

In the last 10 - 15 years there is a tendency to use games for educational purposes (Bontchev & Vassileva 2006; Freitas & Liarokapis 2011; Hristov et al. 2022). Play has always been the natural way to explore the world around us no matter our age, gender, or nationality. That statement is true especially in the early years of child development (Dawley & Dede 2014). In addition, video game development technologies are becoming even more user friendly and accessible (Chang 2022). Traditional physical tools for conducting road safety trainings, such as plastic road signs, physical playgrounds and traffic lights can easily be substituted for virtual ones, with or without VR headsets. Frameworks and game engines, such as Unreal Engine, Unity 3D, or Cryengine allow researchers to create virtual environments, web-based tools, 2D and 3D avatars, develop educational scenarios and training situations, which are either too expensive, not scalable, or not accessible enough using traditional teaching methodologies. Furthermore, content (i.e. “smart assets”), created for one of those platforms can be moved to another game engine environment (Becker 2016).

The main purpose of this research is to show that a collection of specially-crafted road safety scenarios and situations can be combined in a unified web-based virtual environment and be used for effective training. The game engines and frameworks mentioned above allow easy ways for cross-compilation of the game code and educational content to another platform, such as Android, iOS, Linux, web-based environment (via the WebGL API) with the push of a button. That way, the scalability and interoperability of the educational content is increased. In the current research we design, implement and evaluate such an educational tool for road safety we call RS E-book. The educational tool is intended for use via a web browser on a desktop PC. However, we decided to create a mobile app for Android devices, which are widely-available in primary schools. The RS E-book is intended for use of first grade students. However, future versions will support more road safety scenarios, suitable for second, third and fourth grade students. The rest of the paper is organized as follows. Firstly, we have investigated related studies in this domain and noted some prevailing tendencies. Secondly, we describe the software architecture, used for realization of the current project. Thirdly, we conduct several experiments and present the results. Finally, we draw conclusions and mention future aspects of the current research.

## **2. Related work**

Some researchers refer to virtual learning environments as ‘serious games’. The term was first used by Clark C. Abt in 1970 in his book *Serious Games*. In the term, he included board and digital games. Serious games have a clear educational purpose and are not intended for entertainment. However, this does not mean that these games cannot be fun. The modern understanding of the term serious games comes from Sawyer and Rejeski’s *Origins of Serious Games*. This book generated considerable interest in the idea that public and private educational institutions should utilize modern information and communication technologies to produce video games and simulations that target and study real-world problems (Sawyer & Rejeski 2002). The most widely accepted definition of the term is that of Mike Zyda, one of its creators. Its official definition is “Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives” (Zyda 2005).

The problem with road safety is serious, especially regarding young pedestrians. For instance, road traffic incidents, resulting in patients’ major trauma in Australia alone, are 8066 for the 2007 - 2015 period (Beck et al. 2017), and are the second leading cause for injury-related hospitalizations and death. Therefore, there are various examples of virtual realities research, related to

road safety. One such example is the work of (Paulo & Castro 2016). In it the authors stress on the importance of knowing abiding road traffic signs and regulations. Their educational road safety mobile game helps children aged 9-12 familiarize themselves with known and unknown situations they might encounter during their daily commute. The authors claim training with such virtual scenarios – crossing a street or railroad tracks, being aware of vehicles, traffic lights, road signs, etc. can prevent or at least reduce the risk of road accidents related to children. Other authors (Husain et al. 2022) focus their research on the use of sensors and natural user interface for creating road safety serious games.

Other researchers (Szczurowski & Smith 2018) make use of virtual reality (VR) headsets to train and educate road safety rules to youngsters. In their study, the authors rely on the great ability of modern VR systems to recreate believable everyday life situations. That way, children will not only learn by filling-in textbooks or answer questions, but also be physically involved. As a result, the formation of autobiographical memories occurs, resulting in an increased knowledge retention and transfer (Seymour et al. 2002). Last but not the least is the work of (Gounaridou et al. 2021), who examine the navigation and orientation of human-controlled avatars in 3D virtual environments. Their approach investigates how road safety games can be engaging, amusing, and efficient. Furthermore, the authors showed the relative inefficiency of studying road safety rules in the classroom and the lack of proper and adequate training during the first four years of children's education on road safety.

### **3. Game design**

Following some of the downfalls of traditional educational approaches regarding road safety (via a text-based notebook or static multimedia), the RS E-book is created as an alternative tool of teaching. In its original physical form, students fill-in various road safety exercises and then take a final exam. Players use pens or crayons to draw circles, arrows and other shapes to solve the road safety situations. As a digital successor, RS E-book inherits much of its original concept. Most of those tools were adapted and some even re-designed for use in the digital environment rather than copied straightaway from the textbook.

### **4. Educational methodology**

The study programs in preschool and elementary schools in Bulgaria are ratified for road safety training (RST) by the Minister of Education and Science, in accordance with According to Order №RD09-2684 from 20.9.2018<sup>1</sup>. The above-mentioned programs came into effect during the 2018 – 2019

school year. Furthermore, on 02.03.2021 the Order number RD09-5282 ratifies the Road Safety Strategy, issued by the Bulgarian Ministry of Education and Science. One of the key objectives of the strategy is to provide “Effective road safety training in the preschool and school education ... and as a result to reduce the road-related accidents involving children”<sup>2</sup>. Action plans for fulfilling that key objective are constantly being put into place. As such, the Action plan of the Bulgarian Ministry of Education and Science for 2023 regarding Road Safety<sup>3</sup> includes work tracks “Integrity-based management” and “Socially responsive behavior: life-long learning”. One of the intended purposes of those tracks is “Life-threatening risks prevention of children as participants in everyday road traffic”<sup>3</sup>. The road safety education is firstly introduced during early kindergarten courses and continues being studied up until XII grade. This is a highly important topic that should educate young children about the dangers of road crossing and moving by the road, so that they build a self-preservation instinct.

The current study is focused on first grade students. The presented RS E-book contains scenarios, which are appropriate for the road safety education of first grade children<sup>4</sup>. According to the Ministry of Education and Science, the minimal recommended education hours of road safety for first grade students are 9 academic hours (35 minutes each), of which 6 hours for practical education and the rest – for theory. The road safety education should be carried out during the “class hour” and teachers are required to schedule in advance its execution. Students get initially acquainted with different pedagogical scenarios as early as preschool. In first grade they further develop their road safety awareness skills by focusing their attention on the subject.

The specifics of teaching road safety to first grade students suggest the employment of game-based methods and roleplaying. These methods enable the students to experience critical road-related situations in a realistic and safe environment. Serious games are expected to simulate the results of the players’ actions provided the programmed situations were real. The assignments in game form allow students to be the active party in the learning process by giving them the opportunity to communicate, collaborate, and apply in practice their theoretical knowledge. Depending on the chosen scenario, serious games can be successfully combined with the principles of problem-solving education, project-based education and learning by doing. Game-based learning is in close connection with the STEM principles (Mihov & Dimitrov 2022), (Mihov et al. 2022), (Papancheva & Dermendzhieva 2020). Furthermore, the game-based methodology is in close relation with the 21st century study framework<sup>5</sup> known as the four “C” (creativity, critical thinking, communication, collaboration). Game-based learning can be implemented by using virtual learning platforms for road safety. These platforms provide

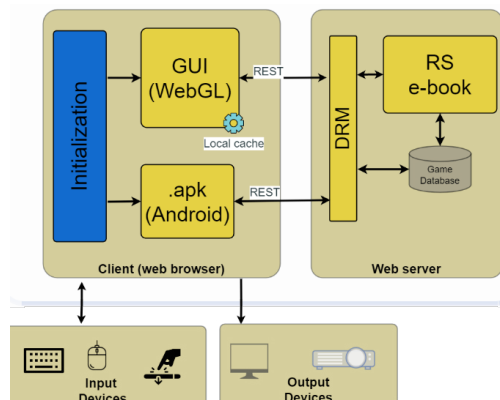
a good alternative to traditional learning methods and allow interactivity and inclusiveness. The interactive nature of such platforms facilitates the process of acquiring and attaining student attention for longer periods.

The web-based RS E-book contains different type of tasks – listening, reading, filling in the gaps, sliding, connecting and circling objects. These tasks give students the opportunity of interdisciplinary learning by including not only road safety knowledge, but also subjects such as mathematics, Bulgarian language and literature. For instance, once task requires players to count the number of vehicles on the presented image. Another task asks students to fill-in a missing letter in a road-related term. On the other hand, each task is described in a text form, which allows students to practice their reading and comprehension skills. At the beginning of the school year the students lack sufficient knowledge for independent reading and their teachers are the ones that assist them in that endeavor. Furthermore, as students get better and better at their Bulgarian language and literature classes, the RS E-book gives them an additional way of exercising, related with reading.

The approach the RS E-book took in presenting the road safety tasks as game-based learning scenarios motivates students to discover new ways and explore new ideas. Children learn to observe, to explore, to experiment, to solve problems and to show initiative.

## 5. System software architecture

The system design of the RS E-book is centered on the client-server approach. An overview of the architecture is presented in fig. 1. The architecture is extended with a digital rights management (DRM) module that restricts access to unauthorized users.



**Figure 1.** A client-server architecture of RS e-book with added DRM module

Initially, the players access the game via a web browser on a desktop machine or through the android app (clients). After some initialization and information screens, they are presented with the interface of the DRM module. The latter serves as a protection module to keep unauthorized users away, since the game URL can be accessed from any location. Then, players need to enter their 6-character access keys in order to access the training scenarios (fig. 2). For access keys, we generate random alpha-numerical characters, checking if the generated key already exists in the database. Of course, a more sophisticated cryptographic and authentication approach can be used but for all intents and purposes the suggested approach performs reasonably well.



**Figure 2.** The DRM module access screen

In the DRM administration system, we have defined two roles: administrators and users. The administrators can generate, edit, view and delete keys, with each key being associated with a particular school. For non-school end customers, the DRM administrators can create a “dummy” school, with which new user keys can be associated. All generated keys are kept in an encrypted database, located on the server side (fig. 1).

In order to minimize client-server calls, the whole game is cached on the client’s browser upon initial load of the webpage. Sequential calls are made to the server via REST methods. Those calls are needed for preservation of the current player progress (i.e. which situation the user is currently working on and the total number of points). Additional parameter, passed during the calls, is the unique user access key. In the event that the access key is invalid or expired, the user is denied access to the RS E-book backend.

## 6. Scoring system



**Figure 3a, 3b.** Green (a) and red (b) points (upper left) are represented as a traffic light. Players get hints (colored in red) for re-attempted scenarios

The scoring system differs from the traditional accumulation of points, present in serious games (Laamarti 2014). From a pedagogical point of view, it is important to make note of the number of attempts users are allowed to solve a situation or answer a road safety related question. First-time correct answers are awarded a green point, whereas wrong answers and subsequent attempts are awarded a red point. To emphasize the importance of first-time correct answers, they are visualized as a green traffic light in the top-left corner of the UI, whereas red points are drawn as a red traffic light (Figure 3a and Figure 3b). In addition, there are correct and incorrect animations that play after each situation solving attempts.

Answering correctly for the first time rewards the player with an animation of a car that passes a rising barrier. In contrast, answering wrongly plays an animation, in which the car stops in front of a barrier and then circles back around for another try. In addition, there are road signs in the above-mentioned animations, facilitating further the knowledge of street safety. Adding such gameplay elements seem to facilitate the learning process, as we will see in the experiments section. There is also a more traditional scoring system – accumulating only one type of points, which is only present for the examination section. The reason for the latter is that during testing, students have limited time to answer all questions. Therefore, giving them immediate feedback before the test is over is not desirable. All the points, gathered during the training, as well as examination exercises, can be viewed and stored as PDF files for later reference.



## 7. Experiments and results

How effective is the RS E-book in teaching road safety rules? To answer this question, we compare it with its textbook counterpart, containing the same scenarios. For this experiment, we form two groups of first grade children, consisting of 10 children each. The experiment is conducted at the end of the school year and therefore students are literate in reading and understanding the road safety scenarios. Students for both groups are picked at random and therefore no a priori knowledge of superiority of one group over the other is present.

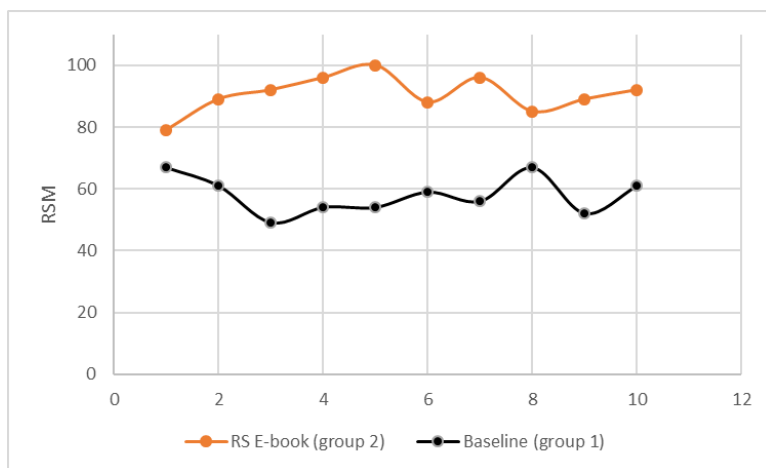
The first group studies the traditional, textbook way. Its performance, measured by the number of points, serves as the experiment baseline. Finally, the first group is examined on the paper test. The other group learns the road safety scenarios via the RS E-book. The other group is examined digitally, but using the same scenarios and test questions. Our evaluation metrics are the total number of accumulated green and red points during training and total number of points, gained during the examination part of the course. We define a road safety metric (RSM), which combines all the gathered points in a meaningful way. RSM is calculated as a percentage:

$$\text{RSM} = \frac{G + E}{N + R} \times 100$$

where  $G$  is the total number of green points,  $R$  is the total number of red points,  $E$  is the number of points during examination, and  $N$  is the total number of questions/scenarios. We penalize additionally for red points ( $N + R$ ), because of the importance for children's health safety if they learn the wrong rules and repeat the in the physical world, as suggested by (Paulo & Castro 2016). For the current study, the total number of training questions is 46, with addition 4 examination questions, resulting in  $N = 50$ . The summarized results are presented in Figure 4.

As we can see, group 2, studying using the RS E-book outperforms group 1 that studies via traditional textbooks. There is a benefit, but is that performance increase significant? To answer that question, we evaluate the results by performing a one-tailed t-test. The 10 participants of group 2 (test group) who took part in the test ( $M = 90.6$ ,  $SD = 5.73$ ) compared to the 10 participants in the baseline group ( $M = 58$ ,  $SD = 5.78$ ) resulted in  $t\text{-value} = -12.02$ . The  $p\text{-value}$  is  $< 0.00001$ . The result is significant at  $p < 0.05$ .





**Figure 4.** Plot of the RSM for both baseline and evaluation groups of first grade students

## 8. Conclusion

In this paper, we presented a novel approach for design and development of a game-based educational tool for road safety, the RS E-book. We designed, implement and evaluate the new road safety-learning tool by comparing it with its textbook counterpart. We showed the importance and relevance of such digital tools and the role they play in preserving human lives. In addition, we performed standard statistical analysis (one-tailed t-test) to demonstrate the significance of the reported results. We do take notice of the relatively small number of students in both evaluation groups and plan to expand the study with more participants in the near future.

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## NOTES

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