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VIRPA Fire expert

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Virpa3 Final Report:

Gamification and Technology in Fire Safety Education

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1 Introduction

The Virpa project series, i.e., Virpa, Virpa2, and Virpa3, represents an innovative and strategic effort to transform fire safety education for children through digital, immersive, and engaging technologies. It began with a groundbreaking question: could virtual and augmented reality be effectively used to teach essential fire safety knowledge, skills, and attitudes?

Over the course of Virpa1, Virpa2, and Virpa3, the project evolved significantly, from using virtual reality (VR) for behavioral research to developing an engaging and gamified mobile learning environment for children aged 7 to 13. The series has not only contributed to the academic understanding of fire safety education but also generated real-world impact by addressing the gaps identified in traditional fire safety curricula.

Throughout these projects, we have collected extensive research data, collaborated with schools and fire safety departments, and made significant strides in incorporating innovative teaching methods into fire safety education.

This report presents the comprehensive outcomes and impact of the Virpa3 project, reflecting on the challenges overcome, the technological advancements achieved, and the substantial impact made on key stakeholder groups, including schools, fire departments, and the research community.

2 Background

The story of the Virpa project series began with a simple question: could virtual reality (VR) be used as an effective tool to teach fire safety? At the outset, there was no clear roadmap for a series of projects, nor an assumption that existing fire safety education methods would require improvements. The goal of the first Virpa project (referred to in this report as Virpa1, an acronym derived from "virtuaalitodellisuus paloturvallisuus viestinnän välineenä") was to explore the potential of VR for fire safety communication in innovative ways. Rather than creating a traditional educational tool, the project aimed to utilize VR as a research instrument to collect data on human behavior during unexpected fire emergencies in unfamiliar settings.

The Virpa1 project developed and tested a VR simulator that replicated a realistic office building fire scenario. A critical focus was placed on modeling the behavior of smoke, a major factor contributing to fire-related fatalities. Participants navigated this virtual environment, making real-time decisions on how to respond to the fire, such as identifying escape routes, avoiding smoke-filled areas, and reacting to alarms. In total, 169 individuals from four distinct target groups—upper primary school students, young adult students, working adults, and fire safety professionals—participated in the study. Before the simulation, participants were briefed under the premise that it was a work interview exercise in an office building. They were instructed to behave as they would in a real-life situation. Their actions were tracked using 21 behavioral metrics, such as the time taken to start evacuating after hearing the fire alarm, total evacuation time, and eye contact with exit signs.

The data gathered provided valuable insights into decision-making processes during fire emergencies, revealing significant differences in behavior between age and experience groups. Post-simulation questionnaires and interviews further assessed participants' perceptions of the VR experience and their understanding of fire safety. Notably, younger children had difficulties identifying fire safety signs and evacuation routes within the VR simulation. These findings suggested and confirmed that VR was an effective research tool for understanding human behavior in emergency scenarios. We felt that a continuation project would require the application of educational mediums more accessible to younger audiences. The results of Virpa1 served as the foundation for the subsequent projects, Virpa2 and Virpa3.

Connection to Current Fire Safety Education Needs

The findings from Virpa1 emphasized the importance of fire safety education for young audiences, aligning with the stipulations of the Basic Act for Education (Perusopetuslaki, 2016), which mandates a safe learning environment for all students. Additionally, the National Core Curriculum for Basic Education (2014) requires fire safety to be included in health education for grades 7–9 and environmental studies for grades 3–6. However, these mandates lack specific guidelines on how to implement effective fire safety education, underscoring the relevance of innovative tools like Virpa.

Virpa2, building on the insights from Virpa1, aimed to develop a digital and gamified learning environment tailored for children aged 7 to 13. The result was the Virpa – Fire Expert game, a mobile application designed to teach fire safety knowledge, skills, and attitudes in an engaging way. The game is set in a virtual school building with three floors and an outdoor play area. Players progress by exploring classrooms, identifying hazards, solving puzzles, reading real-life fire incident reports, and playing minigames that reinforce fire safety principles.

The gameplay mechanics are designed to encourage interactive learning. Players unlock rooms by scanning real-world fire safety signs and objects with their phone cameras, a feature made possible through a neural network trained on 10,000 photos of fire safety elements. The game covers key fire safety items such as fire alarms, fire extinguishers, and emergency exit signs. Each scanned item leads to a series of questions posed by virtual fire officers, designed to impart knowledge, skills, and positive attitudes towards fire safety.

Challenges, such as the Skateboard minigame, which emphasizes the importance of exit signs in smoke-filled environments, and the Fire Extinguisher AR minigame, which teaches how to extinguish a fire, are central to the experience. Players also participate in a fire drill and engage with hazards like faulty electrical appliances, reinforcing the importance of safety awareness. The game is described in more detail in **Section 3.2**.

The game integrates pedagogical principles by gradually building on knowledge and skills through a progression system that mirrors real-life learning objectives. Early feedback indicated high engagement levels, but it also became evident that further dissemination efforts were necessary to maximize the game's impact. The need for more structured integration into school curricula led to the continuation with Virpa3.

Virpa3 focused on expanding the reach and long-term sustainability of the Virpa – Fire Expert game. This included developing a robust dissemination strategy and implementing technical updates, such as raising the Android API level and updating the Unity engine. These efforts aimed to future-proof the game and align with evolving digital standards, ensuring that it remains a valuable educational tool for years to come.

3 Virpa1 and Virpa2 projects related work

The aims and achievements of the Virpa3 project cannot be fully understood without considering the context established by its predecessors, the Virpa1 and Virpa2 projects. This chapter summarizes the most important results and key findings from both projects.

3.1 Virpa 1

Virpa1 project began with the innovative concept of utilizing virtual reality (VR) as a research tool to collect comprehensive data on human behavior during unexpected fire emergencies in non-familiar settings. Instead of aiming to educate directly, the primary objective was to observe and analyze how individuals of different age and experience groups would naturally react in a high-stress, life-threatening scenario.

The VR fire-scenario simulator was meticulously developed to replicate a realistic and dynamically evolving fire emergency within a simulated office building environment (**Figure 1**). The simulation placed significant emphasis on modeling the behavior of smoke, given that smoke inhalation is one of the leading causes of fatalities in fire incidents. The smoke's movement and spread were simulated using sophisticated fluid dynamics simulation tools, which created an immersive and authentic experience, aiming to elicit genuine behavioral responses from participants (Niinikorpi, 2018). The building layout included multiple rooms, corridors, and exits, with strategic placement of fire safety signs and cues to mirror real-life emergency scenarios.

Participant Experience and Setup: A total of 169 participants were recruited, divided into four distinct target groups: upper primary school students, young adult students, working adults, and fire safety professionals (**Figure 2**). To ensure unbiased and authentic reactions, participants were initially informed that the simulation related to a job interview scenario. They were unaware of the fire emergency aspect, thus creating a realistic surprise element when the fire alarm was triggered. Participants were instructed to behave exactly as they would in real life, making decisions under pressure in a highly immersive environment.

Behavioral Metrics and Data Collection: The VR simulation collected extensive behavioral data through 21 distinct metrics. These metrics included critical measures such as:

- Reaction Time: The duration taken by participants to recognize the fire alarm and initiate evacuation.
- Navigation Patterns: How participants moved through the environment, their chosen routes, and whether they encountered or avoided hazardous areas filled with smoke.
- Eye-Tracking Data: Whether participants noticed and used fire safety signs to aid in their evacuation, with metrics on eye-contact duration and frequency with these signs.
- Decision Points: Key choices made by participants, such as selecting exits, avoiding or entering smoke-filled areas, and adhering to safety cues like alarms.

Post-Simulation Feedback: In addition to real-time behavioral tracking, the project employed post-simulation questionnaires and semi-structured interviews. These instruments gathered qualitative data on participants' perceptions of the VR experience, their understanding of fire safety concepts, and their reflections on the decisions they made during the emergency. The feedback provided a dual-layered perspective: both the observed behavior during the simulation and the participants' self-reported understanding and awareness.

Key Findings and Insights: The collected data revealed critical differences in how each age and experience group responded to the simulated fire scenario. Notably, younger children exhibited difficulties in recognizing fire safety signs and understanding effective evacuation routes, often choosing inefficient or hazardous paths. In contrast, fire safety professionals demonstrated significantly quicker reaction times and a more systematic approach to evacuation, utilizing fire safety cues effectively. These findings underscored the potential of VR as a research tool for examining human behavior in emergencies, highlighting both its strengths in simulating realistic stress responses and its limitations in direct educational applicability for younger audiences.

The insights gained from Virpa1 laid the groundwork for the subsequent Virpa2 and Virpa3 projects, which shifted focus towards developing educational tools better suited for engaging and teaching younger age groups. The comprehensive findings of Virpa1 were published in several academic journals and conference proceedings, including Oliva et al. (2019), Somerkoski et al. (2020), and Tarkkanen et al. (2020), while the advanced smoke modeling techniques used were documented in Niinikorpi (2018).

Figure 1. Screen captures from the VR simulator developed during Virpa1 project.

Figure 2. (from left to right) School students, young adult students, and fire safety professionals participating in Virpa1 research.

3.2 Virpa2 project implementation and the Virpa - Fire Expert game

Building on the insights from Virpa1, the Virpa2 project aimed to create a robust and gamified learning environment tailored specifically to engage children aged 7 to 13 in the principles of fire safety. Recognizing the limitations of VR for younger audiences, Virpa2 shifted its focus to developing a mobile

game, named Virpa – Fire Expert, which employed both traditional and augmented reality (AR) elements to create a compelling educational experience.

Design and Structure of Virpa – Fire Expert

The game is set in a virtual school environment that spans three floors and includes an outdoor play-yard (**Figure 3A**). Players can freely explore this environment using an open-world framework, but a carefully structured progression system guides them to unlock classrooms in a pedagogically logical sequence. The progression system relates to the pedagogic approach to taught in a logic order the knowledge, the skills, and the attitudes of fire safety topics. The player unlocks these classrooms (**Figure 3B**) by scanning with the phone camera fire safety objects and related signs in real-world buildings (**Figure 3C**). To enable this functionality, we trained the system's neural network with 10000 photos taken by our team members, about 1000 photos per sign or object we wanted the players to learn about. The objects and signs that can be scanned and recognized by the system are:

- Fire alarm sign
- Fire alarm button sign
- Fire alarm button
- Fire extinguisher sign
- Fire extinguisher
- Emergency exit sign
- Fire hose sign
- Defibrillator sign
- Meeting point sign

Typically, scanning one sign or object allows the player to enter the first room out of three dedicated to that item. Inside the room the player encounters a fire officer (**Figure 3D**), who asks a question related to the general knowledge related to that item. Correct answering grants the player a Bronze Star. That Bronze Star and a second scanning of the same item grants permission to enter the second dedicated room, where another officer asks a question related to the skills. Gaining the Silver Star and performing a third scanning allows to enter the last room dedicated to that sign, where the player doesn't need to answer any question, but reads instead a text regarding a positive attitude about the use of that object. This grants the Gold Star. Further on, gaining six Gold Stars allows entering the Final Exam room, where the previous 12 questions are repeated in addition to six extra ones (total 18 questions). The player receives a gold, silver or bronze "fire expert" diploma based on the number of correct answers.

Minigames and Interactive Learning Components

Virpa – Fire Expert includes three minigames, each designed to reinforce essential fire safety concepts through interactive challenges:

- Skateboard Minigame: Players navigate a maze-like corridor filling with smoke, using exit signs to find their way out quickly and safely (**Figure 3E**). This game emphasizes the importance of recognizing and following exit signs.
- Fireman Minigame: A reimagined version of the classic PAC-MAN™ game, where players must evacuate a building and avoid dangers while collecting important items (**Figure 3F**). It reinforces the urgency of evacuation during emergencies.
- Fire Extinguisher AR Minigame: Utilizing AR, this game projects a virtual fire into the player's physical surroundings (**Figure 3G**). Players must effectively use a virtual fire extinguisher to put out the flames, teaching the correct technique for handling fire extinguishers.
- Fire Drill: Fire Drill activity activated in a hidden room within the library (**Figure 3H**). Players practice an orderly evacuation, which can also be performed with the lights off to simulate more challenging conditions (**Figure 3I**).
- Hazards, Puzzles, and News: Players encounter and mitigate nine fire-related hazards scattered throughout the school and learn through the information placed in some of the chalkboards. Examples of hazards include a coffee machine with a damaged electric cord (**Figure 3J**) and a mobile phone charging dangerously near water. Hazards appear to teach how to identify unsafe conditions in real life. Puzzle solving in the chalkboards included the use of fire blankets (**Figure 3K**) or when to change the batteries of fire detectors. News were a collection of six collectible newspapers, each containing real stories about fire incidents in Finnish schools (**Figure 3L**).
- Collectibles: In addition, we allowed players to customize their boy and girl avatars with up to 40 different clothing items, adding a layer of personalization and engagement to the game.

Gameplay Mechanics and Scoring

Every action in the game contributes to the player's total score, which can be viewed on a leaderboard comparing performance with other players. Players can access comprehensive menus that provide information on collected items, completed and pending tasks, floor plans, and overall game objectives. Importantly, the AR scanning feature awards diminishing points with repeated scans of the same item in the same location to discourage score inflation and promote genuine exploration.

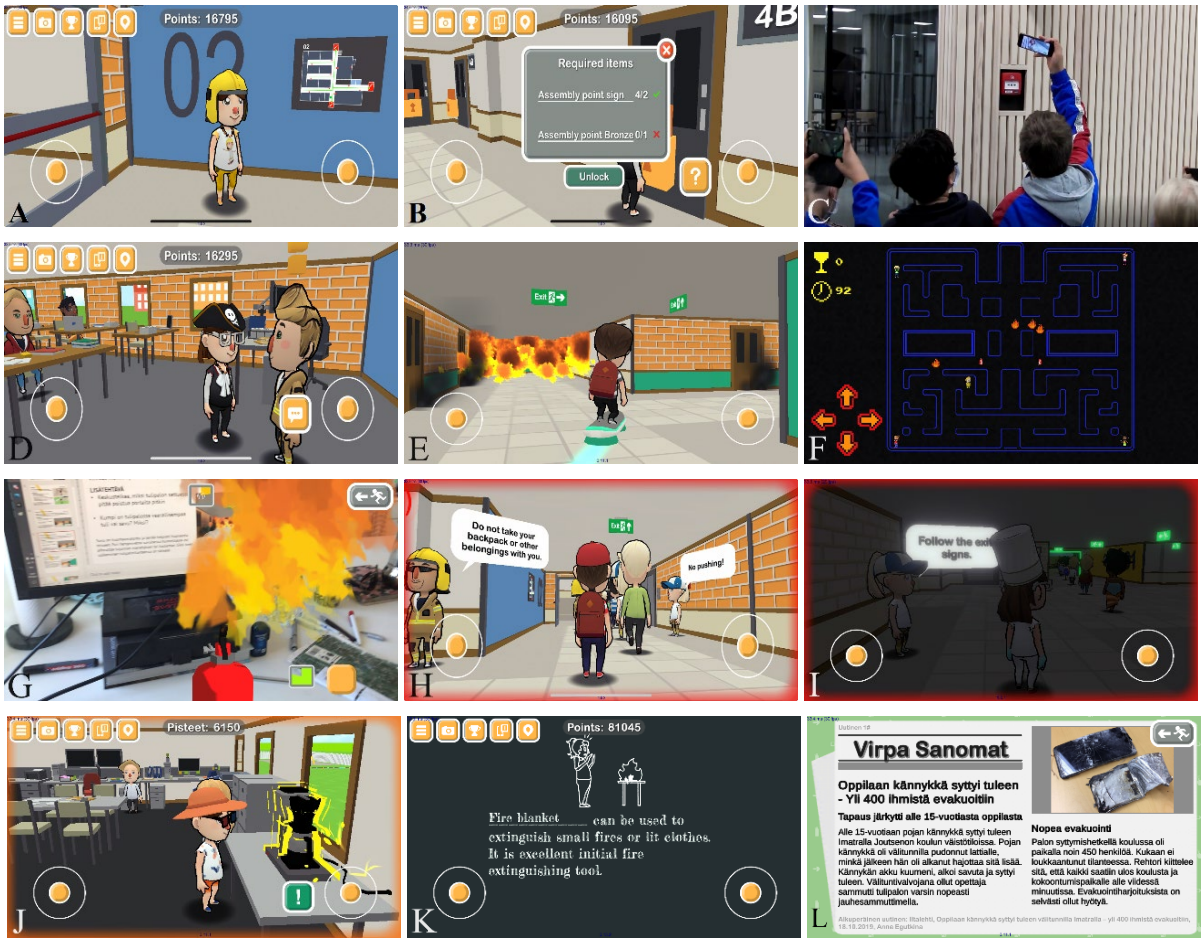

Figure 3. A) Avatar observing floor plan, which could be further amplified for inspection. B) Information displayed to player for the unlocking of Room 1A. C) Children scanning with the phone camera fire-safety signs and objects in real buildings to unlock doors in the game (Photo by Juha Paju-Heikkilä). D) Avatar in front of the fire officer who will ask a fire safety question related to the corresponding scanned sign or object. E) A capture of the skateboard minigame that teaches the importance of exit signs. F) A capture of the fireman minigame that teaches the importance of evacuating a building in case of emergencies. G) A capture of the fire extinguisher minigame which applies augmented reality to display a virtual fire in the real environment where players play the game. H) A capture of the fire drill minigame where kids learn how to exit promptly but not rushing the school building. I) A capture of the fire drill minigame with lights off. J) One of the nine hazards, i.e., electric machine with damaged cable, that can be found in the school. K) One of the 12 puzzles, i.e., how to use the fire blanket, that can be found in the classrooms' chalkboards. L) One of the six newspapers with news.

Availability and Language Support

Virpa – Fire Expert is available for both iOS and Android devices, and appears free and with no commercials of any type in app stores. It includes translation to Finnish, Swedish, and English, making it accessible to a broader audience. The latest version updated in November 2024 includes text-to-speech functionality to make it more accessible.

Pedagogical Impact and Early Feedback

The game was designed to align with educational best practices, balancing fun and learning. Initial feedback from test groups highlighted the game's success in engaging children and effectively teaching fire safety concepts. However, the project team soon recognized that the game's adoption was limited, prompting the need for a focused dissemination effort. This realization led to the Virpa3 project, which aimed to expand the game's reach and ensure longer-term sustainability.

Virpa3 project's focus shifted toward increasing the dissemination and adoption of the Virpa – Fire Expert game, while also ensuring the game's long-term sustainability through necessary technical updates. The main objectives of Virpa3 were to develop a comprehensive dissemination strategy and to make technical improvements that would improve future-proof of the platform. In the next chapter, we present the results of this new Virpa3 project during the four defined work packages. We organize later in dedicated **Chapter 5** the presentation of all scientific publications that our team members have achieved during the three consecutive Virpa series projects. The impact of the project is analyzed and discussed in **Chapter 6**.

4. Virpa3 – Project Implementation

Building on the foundation laid by the Virpa1 and Virpa2 projects, Virpa3 aimed to amplify the impact of the Virpa – Fire Expert game through strategic dissemination, significant technical enhancements, and comprehensive stakeholder engagement. The primary goal was to ensure the game's long-term sustainability, increase its reach, and continue refining it based on user feedback and emerging technological advancements. This chapter provides a detailed account of the activities carried out under the four work packages (WPs) defined in the project plan.

Virpa3 was launched to address critical gaps identified in Virpa2, specifically the need for broader dissemination and technical updates to future-proof the game against the rapid evolution of mobile platforms. The project was structured into four main work packages: WP1 (Research on Fire Safety Education), WP2 (Verification of Learning and Data Collection), WP3 (Technical Development and Updates), and WP4 (Dissemination and Outreach). Each WP had specific objectives, activities, and outcomes that contributed to achieving the overarching goals of Virpa3.

4.1 Work Package 1: Research on Fire Safety Education

WP1 focused on assessing the current landscape of fire safety education in Finland and identifying best practices, gaps, and opportunities for incorporating digital learning tools like Virpa – Fire Expert. The research carried out a comprehensive study involving schools and fire departments (Väittinen and Rosu, 2022).

4.1.1 Objectives and Methodology

The primary objective of WP1 was to understand how fire safety education is currently delivered in Finnish schools and to explore the perceptions and readiness of educators and fire safety professionals to adopt digital tools. The methods used in this WP included:

- **Literature Review**: A detailed analysis of existing curricula and fire safety guidelines, such as the Basic Act for Education (Perusopetuslaki, 2016) and the National Core Curriculum for Basic Education (Finnish National Agency for Education, 2014).

- **Surveys and Semi-Structured Interviews**: Email contact was made with all 21 Fire Departments of Finland and over 300 schools. Follow-up interviews were conducted with fire safety professionals and educators to gain deeper insights into their perspectives and experiences.

4.1.2 Key Findings

1. **Current Practices**: Fire safety education is inconsistently delivered across schools. Many schools rely on traditional methods such as fire drills and classroom lectures. However, there is limited and unstructured use of digital resources.

2. **Challenges Identified**: Some educators recognized a lack in schools of knowledge and guidelines on how to effectively teach fire safety. Despite Education Acts contain guidelines to include safety and fire safety on their programs, perhaps the teachers had difficulties to figure out how to integrate interesting tools to build their educative yearly programs. This highlights the opportunity for similar gamified tools to provide structured and engaging content, that at same time aligns with the

educational standards. Teachers consistently reported that they lacked engaging, age-appropriate materials for teaching fire safety and expressed maybe some frustration over the limited fire safety content in existing curriculums.

The interviews revealed that while fire safety trainers generally believed that children's fire safety knowledge had improved over the years, that possible thanks to better access to information via social media and the internet, there were significant challenges in maintaining children's engagement during traditional fire safety lessons.

3. **Openness and limitations**: The study revealed a good level of interest among teachers, though fire departments were less likely to use them extensively due to their own dedicated programs. This opened discussions about the usefulness and accessibility of games and external interactive technologies, and what kind of training or modifications would be necessary to better integrate them into existing youth education procedures. Both fire safety trainers and teachers emphasized the need for more practical, hands-on fire safety exercises, especially for younger children. Part of the fire safety trainers indicated that their current training programs were heavily lecture-based, relying on theoretical discussions and the use of PowerPoint presentations, which often failed to capture the attention of younger audiences. Some fire departments offered practical fire drills or extinguisher use exercises, but these were limited in frequency due to resource constraints.

   The feedback underscored the importance of developing more interactive and immersive learning tools, particularly for primary school-aged children. Fire safety trainers noted that also sometimes younger children struggle with understanding the abstract concepts of fire safety, and that real-life demonstrations were often more effective than theoretical lessons also on their presentations.

4. **Role of Virpa – Fire Expert game and gamification to address challenges**: The response of teachers and fire safety trainers to how Virpa – Fire Expert can supplement fire safety education was overwhelmingly positive. Teachers, for instance, found the game's AR-based scanning functionality particularly engaging, as it allowed children to interact with real-world fire safety signs in their everyday school environment. Over the last four years, Virpa team members visited numerous schools and observed the behavior and engagement of hundreds of children. The additional materials we have developed, such as a web-based progress evaluation tool (**Figure 7**, **Section 4.3.6**), should assist teachers in better evaluating the learning achievements of their students. During the Virpa2 project, we also created PowerPoint materials for teachers to facilitate further discussions about the game's concepts (GamiFIN Conference 2022, Levi, Finland). Additional resources published on the project's dedicated website (**Section 4.4.1**) aim to help teachers integrate our materials seamlessly into their curriculum. Nevertheless, fire department educators pointed out time constraints within their existing training schedules as a significant barrier to adopting new digital tools. However, they encouraged the continued development of fire safety curricula and recognized the potential of Virpa – Fire Expert in complementing existing programs.

4.2 Work Package 2: Verification of Learning and Data Collection

WP2 aimed to evaluate the possible learning outcomes of the game. The metric analysis system not only collects gameplay data but also helps to determine how effectively key fire safety knowledge, skills, and attitudes are achieved. The overall goal was to validate the pedagogical value of the game and to understand whether or not it effectively improves fire safety education for children aged 7 to 13.

4.2.1 Playing related metrics

The following lines collect the metrics from 4626 downloads occurred until now (5.11.2024). The majority of these figures are summarized in **Table 1**.

Table 1. Metrics related to game downloads and player engagement.

	N	Percent from total downloads	Percent from qualified players
Total number of downloads	4626		
Qualified players (got score > 0 points)	3395	73 %	
Players still playing after 1 day	2516	54 %	74 %
Players still playing after 30 days	1427	31 %	42 %
Players still playing after 90 days	1056	23 %	31 %
Players still playing after 180 days	696	15 %	21 %
Players scanning fire safety signs	1748	38 %	51 %
Players opening lock doors	1471	32 %	43 %
Players answering Fire Expert questions	1268	27 %	37 %
Players completed final exam	91	2 %	3 %

Engagement

Out of 4626 downloads, we qualified only as players the 3395 players (73%) that did any actions granting score points, like, scanning signs, finding hazards, solving puzzles, or playing minigames. In other words, 1231 downloads (27%) didn't convert to game plays. **Figure 4** illustrates the retention rate, showing the percentage of users who continued playing the game after the initial download date. We measured the game interest with the Retention Rate, because it is one of the most popular key performance indices used in gaming industry to evaluate players engagement. The first data point in the left of the figure represents day 1 after downloading, while the second, third, and forth data points are days 7, 14, and 21 respectively. After that the intervals change to every thirty days. Over half of the players (54.4%) played the game at least a second day, while one third (30.8%) did that at least after one month, and 15% still half a year later. It should be noted that the retention rate is a dynamic index that changes daily as players may return to the game at any time. The plot includes data of recent downloads too, so we don't know how they are going to interact in the future, and therefore this plot represents the newest players only partly. The game was downloaded during the last year 1169 times, and we wanted this data to be considered in the analysis. We maybe would expect that after one year, the retention rate values would stay similar for the first half a year period, but increase maybe 1-3% for the later six months.

In game Interaction

Only, 1748 players out of 4626 (38%) scanned fire-safety signs or objects in real buildings. This function was essential to unlock the 18 rooms where players answer questions to progress on the game, which in turn grants access to the Final Exam room. The total number of scans has been 76802, which averages 44 scans per scanning player (17 scans per player). The average value is misleading, because some players scanned tens of times the same sign, presumably aiming to obtain additional points and rise in the overall ranking. We foresee this sort of behavior by players and counteracted with a rapidly decreasing number of game points by each successive scanning of the same sign in the same 200 by 200 meters grid location.

For interest, we could consider the number of different signs or objects scanned by the N'=1748 players that in total understood and become interested in the scanning functionality to unlock doors.

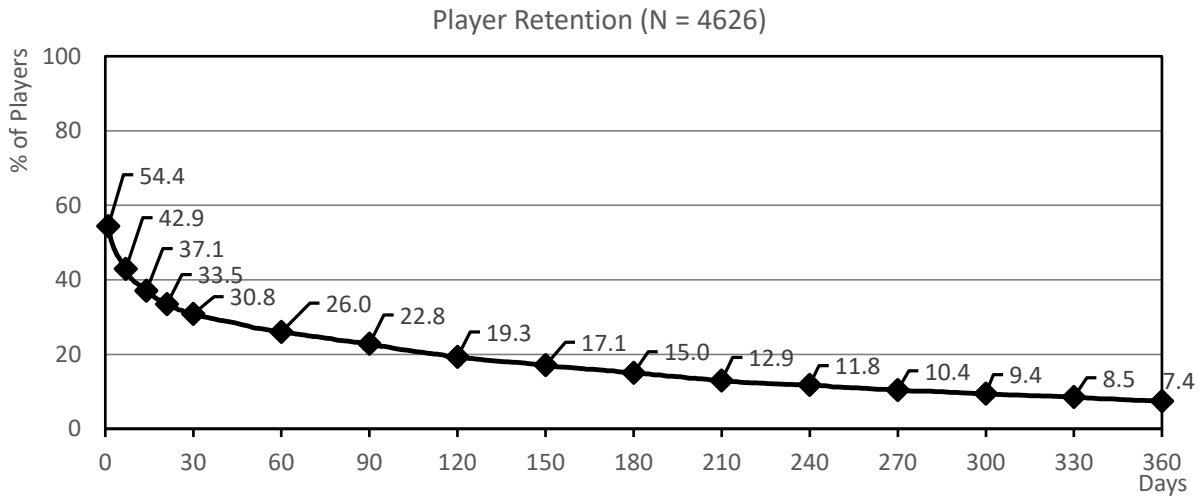

Figure 4. Retention rate of Virpa – Fire Expert game on 5.11.2023 including 4626 players. The chart presents the percent rate of players returning to the game after the app installation date.

Figure 5 explores how the players that learned how to scan signs and use that functionality interact with the game and learn. The data contains all 76802 scans out of the 1748 players who did that. We see that most of the players that scan signs, scan mostly several, e.g., 69% of scanning players identified through the game in real buildings at least five different fire-safety related signs or objects.

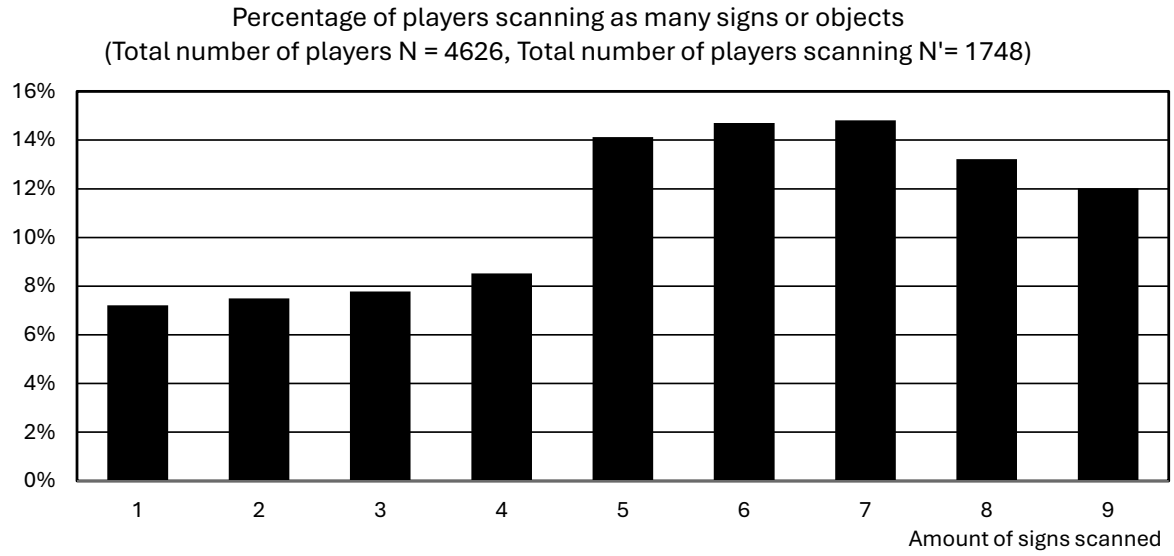

Figure 5. Scanning rate chart presents the percent rate of players scanning a certain number of fire safety signs or objects.

Out of the 1,748 players who used the scanning feature, 1,241 (71%) scanned fire safety signs within only one of the 200x200 meter grid areas into which the game world was divided. This suggests that most players likely scanned signs within a single building, such as their school. Additionally, 20% of scanning players scanned signs in two areas, 5% in three areas, and 4% in four or more areas. This indicates that up

to one-fourth of scanning players may have used the scanning functionality across multiple buildings. It's also worth noting that some larger buildings may span up to four grid areas, i.e., when situated at the intersection of four areas.

Scanning fire safety signs allowed players to enter the rooms, where the fire experts presented questions related to the knowledge, skills, and attitudes related to that sign. As said before, 1748 out of 4626 players scanned signs and objects, 1471 eventually opened the doors and entered these rooms, while 1268 actually answered to at least one of the presented questions. This outcome is not ideal, as it suggests that some players may not have understood the progression mechanics or were content with just playing the minigames and solving various fire safety-related puzzles. It could be argued that the progressing procedure is not self-evident to players. Furthermore, the game required, so far, reading aptitudes from the players or some experience playing open-world type of games. Some kids might not be patient enough to read texts while playing a game. In Virpa we minimized the presence of texts or their importance as much as we could. One of the new functionalities we have introduced in the latest update of the game is the text-to-speech (convers the texts of the game to voice messages), which should improve the accessibility of the game for younger kids or kids not focusing enough on reading (**Section 4.3.2**).

Only 91 players out of 4,626 (2% of total downloads, 5% of scanning players) completed the final exam in the Final Exam Room after unlocking the 18 required rooms. Overall, 61 Gold Diplomas were granted, which was received after answering correctly to 18 fire safety related questions. Sixty-two and 25 Silver and Bronze Diplomas were also granted, those being obtained when answering correctly to at least 16 but less than 18, and at least 14 but less than 16 questions respectively. Overall, 148 diplomas were granted, which in turns indicate that 57 players were not satisfied with the results of their first exam (Silver or Bronze diploma) and succeeded on a second try to improve their grade. Despite only a small portion of players got completed the final exam, till now, it is interesting to see that a good share of those aimed to reach the highest score on that section.

4.2.2 Learning evaluation research

When we first published the game, we performed a series of research activities in schools to evaluate the learning outcomes. This data has been analyzed during some of the scientific materials that now compose part of the scientific outcomes of Virpa series. The analysis is presented now on its final form.

Participants were Finnish comprehensive school pupils aged 9-13 (avg. 10.5 years old) from two schools in Southwest Finland area. They were not rewarded for their participation, neither unaware of the programmed activity during that school day. Permission for interacting and testing was granted in advance by the headmaster, the class teacher, and the parents. The subjects created a nick name they used in both pre- and post-test questionnaires. The pre-test questionnaire, T1, was carried out right before the first game play. The post-test questionnaire, T2, was completed about two weeks later. A total of 260 test subjects participated in T1 (n=260), while only 227 subjects completed T2 (n=227). Based on the nick name, we could combine 193 participants' pre- and post-test questionnaire answers. We further combined their answers with their game play data.

We defined 12 multiple choice questions and two open questions based on our experience studying game learning outcomes and usability. The 14 questions (Q1 – Q14) are presented in the list below, with the options to answer the choice questions in brackets. Questions Q1 – Q9 were presented in both T1 and T2. This allowed the comparison of game play effects in knowledge and behavior of participants. Questions Q10 – Q14 were only presented in T2. They surveyed participants' learning and play experiences.

- Q1. Have you noticed any safety signs in your school? (no/one/many)
- Q2. How many kinds of safety signs have you noticed? (0/1-2/3 or more)
- Q3. How often do you notice fire safety signs? (every day/ every week/ seldom)
- Q4. Do you know where in the school area this sign is [image of assembly point sign]? (no/maybe/yes)

- Q5. Do you know the meaning of this safety sign [image of assembly point sign]? (no/maybe/yes)
- Q6. Have you talked about fire safety with your parents? (no/once/many times)
- Q7. Have you talked about fire safety with your friends? (no/once/many times)
- Q8. How often do you think about fire safety? (never/seldom/every now and then/often)
- Q9. What would you pay attention to if you had to leave a burning school building? (open answer)
- Q10. Have you talked about the Virpa game with your friends? (no/once/many times)
- Q11. What fire safety issues did the game taught you best? (I find the signs easier/ I notice the signs more often/ I know what the signs mean/ I know what to do in case of fire/ I know what to do to avoid fire/ I think more about fire safety)
- Q12. Which part of the game taught you the best fire safety issues? (Scanning signs, Room questions, Newspaper stories, Minigames, Hazards, Final exam)
- Q13. Which one was more fun: playing in the real school or virtual school? (Real school/Virtual school)
- Q14. What was the best in the game play? (open answer).

We performed a distinguished qualitative inductive content analysis to the responses given in the open-ended question Q9. This sort of method is used when the answers are expected to be fragmented, and it allowed us to obtain a holistic picture about how the pupils constructed their understanding. The question was: What would you pay attention to if you had to leave a burning school building? A total of 240 pupils and 203 pupils answered to that question during T1 and T2 respectively. The typical length of an answer was 1 to 3 sentences. The answers were compiled into a matrix, from which the meaning units, for instance individual words (e.g., exit) or related entities of words clusters (e.g., to find the assembly point). Two researchers carried out the categorizing independently and the groups were compared and discussed one by one. Eventually, the responses were divided into 10 main categories. A second round of categorizing answers was carried out by both researchers individually upon the agreed categories, and finally, the meaning units were quantified to calculate the change in answers between T1 and T2.

Figure 6 presents the results to questions Q1 – Q8 in the pre-questionnaire T1 (before game play, n=260) and post-questionnaire T2 (two weeks after first game play, n'=227). Questions Q1 – Q3 related to practical fire safety skills and behavior. In T1, 22% of pupils answered they had not seen any fire safety signs in their school (Q1), but in T2 that possibility almost dropped to zero, i.e., nearly all respondents acknowledge the existence of fire safety signs. The percentage of respondents who have observed many signs increased from 57% in T1 to 96% in T2 (relative increment of 49%). The percentage of pupils who observed three or more types of signs (Q2) increased from 27% in T1 to 88% in T2 (relative increment 180%). The percentage observing the signs every day (Q3) increased from 29% to 55% (relative increment 67%).

Questions Q4 and Q5 were about fire safety knowledge. The percentage of respondents who knew the location of the assembly point sign in their own school (Q4) increased from 1 to 9 respondents. Yet 83% of the respondents did not know where the assembly point sign was located. The truth behind that poor result is that those schools didn't have in fact the assembly point sign placed outside their own building. Only about 1% of the respondents (3 participants) answered that they know the meaning of the assembly point sign (Q5) before the game play, but that increased to 22% of respondents (49 participants) after the game was played.

Playing the game did not significantly impact on how much the pupils talk about fire safety with their friends or their parents (questions Q6 and Q7). Interestingly, the percentage of kids talking many times about it decreased in T2. Thinking about fire safety (question Q8) only increased slightly.

The distinguished content analysis in the open-ended question Q9: What would you pay attention to if you had to leave a burning school building? resulted in ten categories, see **Table 2**. Two positive changes were found. Thirty eight percent less respondents talked in T2 about taking or leaving things in the case of emergency (discourse of things and objects). We believe that after playing the game, kids have learned the importance of promptly exiting a building in case of an emergency. Additionally, there was a 141% increase of the meaning units mentioning the safety or exit signs. Statistical significances have not been calculated,

yet other changes between T1 and T2 seem quite minor. Overall, this may suggest that the two-week period with varying amount of game play had not been effective enough to change how participants think they would act in case of a fire emergency. Nevertheless, we think this categorization is valuable knowledge for fire safety communication itself, even without quantification. The spontaneous open answers may portray the most truthful picture of fire safety knowledge, skills and attitudes among participants that the gaming interventions can be compared with.

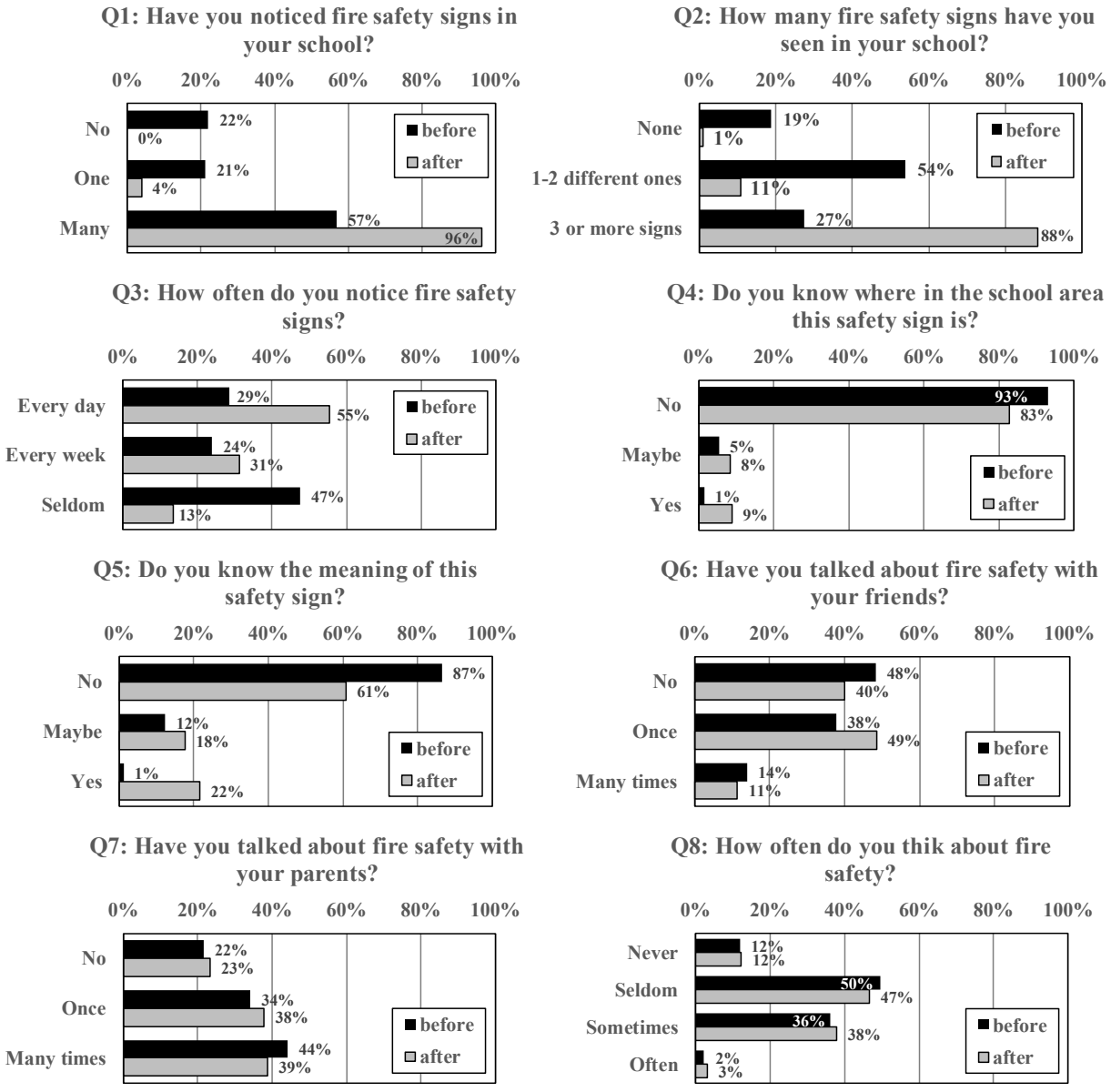

Figure 6. Percentual responses by school pupils to questions Q1 – Q8 before playing the game (T1, n=260) and approximately two weeks after playing the game for the first time (T2, n'=227).

Table 2. Categories, responds of players before and after, and relative change with respect to the open question Q9: What would you pay attention to if you had to leave a burning school building?

Categories	before %	after %	change %
Discourse of things: what to take or leave	13.9	8.6	-38.1
Paying attention to others: following, watching, helping	21.2	21.0	-0.9
Following the given instructions	8.7	0.1	-99.0
Watching the safety signs	2.8	6.9	146.4
Planning a safe exit out; routing	11.5	12.7	10.4
Being calm when exiting; not panicking	7.3	8.4	15.1
How to respond to the fire and smoke: breathing, crawling	15.4	15.8	2.6
Evacuating rapidly; immediate actions	6.1	5.7	-6.6
Evacuation in general, decision making	7.9	5.6	-29.1
Empty or inappropriate answers	5.1	7.0	37.3

In question Q11: What fire safety issues did the game taught you best? Select one or more options. The options "I find the signs more easily" and "I know what the signs mean" were the most selected (59% and 53% of all respondents). Note that Q11 was only asked during T2, after the game was played and not before. In line with the answers in questions Q6, Q7, and Q8, the least answered option here was "I think more often about fire safety", which was still mentioned by 35% of all respondents. Overall, there is a rather even distribution of answers across the different options, which might imply the capability of the game to teach fire safety in a variety of ways without sacrificing any aspect. Each respondent selected 2.8 out of 6 options, which seem to support this assumption.

Different elements within the game seem to be in balance in terms of perceived learning. Question Q12, Which part of the game taught you the best fire safety issues?, was a multi-selection question. The possible categories and the percent of players selecting each category were: Scanning signs (57%), Room questions (37%), Newspaper stories (21%), Minigames (44%), Hazards (34%), Final exam (14%). Only teachability of the final exam remains rather poor, but the explanation is that accessing the Final Exam Room requires a strong commitment with the game and only a minor proportion of players got that far. The most important element in the game in terms of subjective learning was, as expected, the search and scanning of signs. Mini-games are mentioned as the second most important in terms of learning, but mini-games were also clearly perceived as the best aspect of the game (see question Q14), which may affect the perceived learning of the respondents.

Question Q13, Which one was more fun: playing in the real school or virtual school? was surprisingly answered equally. Half of the respondents choose the Real School (e.g. searching and scanning signs) while the other half selected the Virtual School (e.g. playing everything else). We like to interpret this interesting result as the success of the game to find the right balance between playing in real and virtual worlds using AR technology.

We asked what the best part of the game was in open-ended question Q14. The qualitative content analysis, like in question Q9, produced four themes: 49% of the respondents liked the minigames the most, scanning signs was selected by 21%, whereas 7% liked most the questions and answers. Other actions were preferred by 23% of respondents.

4.2.3 Outcomes and key findings from research work

The research conducted in WP2 confirmed the Virpa – Fire Expert game's potential to improve fire safety knowledge and influence behavior among young learners. The key findings, based on both the gameplay

metrics and pre- and post-questionnaires, indicate that the game achieved several important learning outcomes, but also highlighted areas where further improvement is necessary.

- **Improved Recognition of Fire Safety Signs**

  One of the most significant results of the study was the marked improvement in participants' ability to recognize fire safety signs. After playing the game, 96% of participants reported noticing multiple fire safety signs in their environment, compared to only 57% before gameplay. Additionally, the number of students who could recognize three or more types of fire safety signs increased from 27% until 88%, demonstrating that the game effectively taught players to pay closer attention to their surroundings and identify important safety markers.

- **Behavioral Shifts in Emergency Preparedness**

  The content analysis of responses to the open-ended question on how students would behave in a fire emergency revealed promising changes. There was a 141% increase in responses mentioning the importance of safety or exit signs, indicating that players had internalized the critical need to follow safety cues in emergency situations. Furthermore, there was a significant 38% reduction in responses that focused on irrelevant concerns, such as taking personal belongings during a fire evacuation. These shifts suggest that the game successfully promoted more appropriate emergency behaviors.

- **Engagement with Interactive Features**

  The analysis of gameplay data revealed that the AR-based scanning of fire safety signs and objects was the most impactful feature, with 57% of players identifying it as the most effective learning tool. The minigames, which accounted for 43% of preferred learning elements, also played a crucial role in reinforcing fire safety concepts. These findings suggest that the combination of practical, real-world scanning tasks and interactive, virtual minigames created a balanced and engaging learning experience for players. However, access to the final exam, which only 2% of players completed, highlighted a challenge in ensuring that more players engage deeply enough with the game to reach advanced content.

- **Retention and Continued Engagement**

  The retention rate of the game was a key metric for assessing player engagement over time. While 45.6% of players did not return after the initial play session, over 30% were still playing the game after one month, indicating a high level of sustained engagement. Our experience in game development tells that such engagement is hard to reach by a mobile game, especially for educational purposes. Although retention declined after the first month, the fact that nearly a third of players remained active suggested that the game was compelling enough to maintain interest for a significant portion of users.

- **Challenges in Long-Term Attitude Change**

  Despite the improvements in recognizing fire safety signs and understanding emergency behavior, the game's impact on changing long-term attitudes towards fire safety was less pronounced. For example, during the questionnaire experience, only modest increases were observed in how often players thought about fire safety in their daily lives. However, we have not done the necessary research to verify long-term attitudes of the four thousand players that have so far played the game. Nevertheless, this finding highlights the need for continued reinforcement and possibly more immersive educational experiences to solidify these attitude shifts over time.

4.3 Work Package 3: Technical Development and Updates

WP3 focused on the technical enhancements necessary to ensure the long-term sustainability and functionality of the Virpa – Fire Expert game, especially considering evolving mobile operating system requirements. The development work entailed significant challenges and strategic decisions to keep the app operational, stable, and compliant with the latest security requirements. The process is tedious, because the system and security requirements differ drastically in different platforms, e.g., iOS/App Store and Android/GooglePlay. Overall, the updates done during Virpa3 project successfully extended the game's lifespan, but however, the work helped us to realize the maintenance needs and the importance of long-term planning and resource allocation. Often, educational technologies created during a RDI project are not updated or maintained in the long term, sometimes never again once the project ends. Our intention is to keep the game available for as many years as possible. We commit to check the situation every August and find a way to perform the required updates and changes.

4.3.1 Upgrading to New API Levels and Dependencies

A major aspect of WP3 was upgrading the Android API level to meet Google's latest requirements, a crucial step for keeping the game available on new devices. The game increased from 31 to 35 Android API level (Android 15), which was achieved through extensive updates and optimizations:

- **Unity Upgrades**
  The transition required upgrading Unity by two major versions, from Unity 2019.3 to Unity 2021.3. This process presented challenges, such as compatibility issues with plugins, lighting, materials, and general render pipeline settings. The development team did a substantial amount of work to address these problems, ensuring the game's existing features and functionality remain intact.

- **Odin Inspector and AR Plugins**
  Updating Unity also affected various plugins integral to the game's functionality, which needed updating. The Odin Inspector plugin, crucial for the game's overall architecture, triggered both warnings and errors under Unity 2021.3, although these did not result in critical issues. The Odin Inspector plugin was successfully updated, and the overall architecture is stable once again. Additionally, AR plugins needed refreshing to comply with new security and permission handling protocols, which occasionally led to inconsistent performance on some devices. The AR functionality is now working and performs better than before.

4.3.2 Text-to-Speech (TTS) Feature for Improved Accessibility

Text-to-Speech (TTS) feature was added to make the game more accessible to younger players and children with reading difficulties. The TTS functionality provided audio narration for key elements of the game, including questions in the virtual classrooms, feedback from the in-game fire experts, and the texts found in the in-game newspapers.

The decision to implement TTS arose from observations during earlier gameplay tests, which indicated that some players, particularly younger children, struggled to fully understand the questions and feedback presented in the game. By adding an auditory component, the game became more inclusive and allowed all players to engage with the content, regardless of their reading proficiency. We expect the TTS feature to enhance the accessibility of the game.

4.3.3 Offline Mode Functionality

The second largest improvement was the implementation of an offline mode. Now this mode allows players to access the majority of the game's features also without online connection, and so it works now well in

cases where parents or educators might prefer devices not constantly connecting to the internet. Issues in most of the games and functionalities were solved, but at the end, using the scanning function to recognize real world fire safety signs and objects requires to communicate with the neural network. Therefore, it is not possible to unlock doors and enter the rooms if the phone is not online at least during the safety signs and objects scanning process. Except that, all other issues have now been fixed and the game has proved to be stable on the latest tests.

4.3.4 Exploration of Multiplayer Functionality

One of the promises on the project plan was the implementation in the game of multiplayer features. Our goal was to enable the possibility of seeing at least four avatars in the same virtual school environment. That would have allowed players to advance together through the various rooms and challenges. We believed, that functionality would have brought social and collaborative character to the progression process.

However, the original architecture of the game was not designed with multiplayer functionality in mind. Implementing this feature was a significant technical challenge. The game's backend would have required a complete overhaul to accommodate the synchronization of multiple players in the same environment. After a thorough investigation, the development team concluded that the risks and time investment required to implement multiplayer were too high to justify within the scope of Virpa3. Exploring work on this feature produced valuable insights into future iterations of the game.

4.3.5 Bug Fixes and Quality of Life Improvements

A key part of WP3 involves addressing various bugs and making improvements to the game's overall user experience. Notably, the Fire Extinguisher AR minigame, which had experienced technical glitches in previous versions, was debugged and improved. The game's interface was also refined to clarify instructions, particularly around the scanning of fire safety signs, which had been a source of confusion for some players during earlier testing phases.

Other improvements included minor adjustments to the game's user interface to enhance the player experience. This involved optimizing the layout of menus, providing clearer feedback on player progression. These changes, while seemingly small, were important to achieve slightly better user-friendliness and to provide more engaging experience, especially for younger players who might struggle with complex interfaces.

4.3.6 Online research and evaluation interface

The Virpa – Fire Expert game was conceived not only as an interactive learning environment but also as a research tool to assess learning outcomes and player engagement. To support educators and researchers in evaluating the game's educational effectiveness, an online evaluation form was developed as part of the project's technical enhancements. Its primary goal was to offer educators, researchers, and parents a comprehensive tool to visualize and assess the progression and learning outcomes of the players (**Figure 7**). The form, accessible through the **www.virpagame.fi** website (direct address https://www.virpagame.fi/database), enables teachers to evaluate how well students have absorbed fire safety knowledge, skills, and attitudes while playing the game.

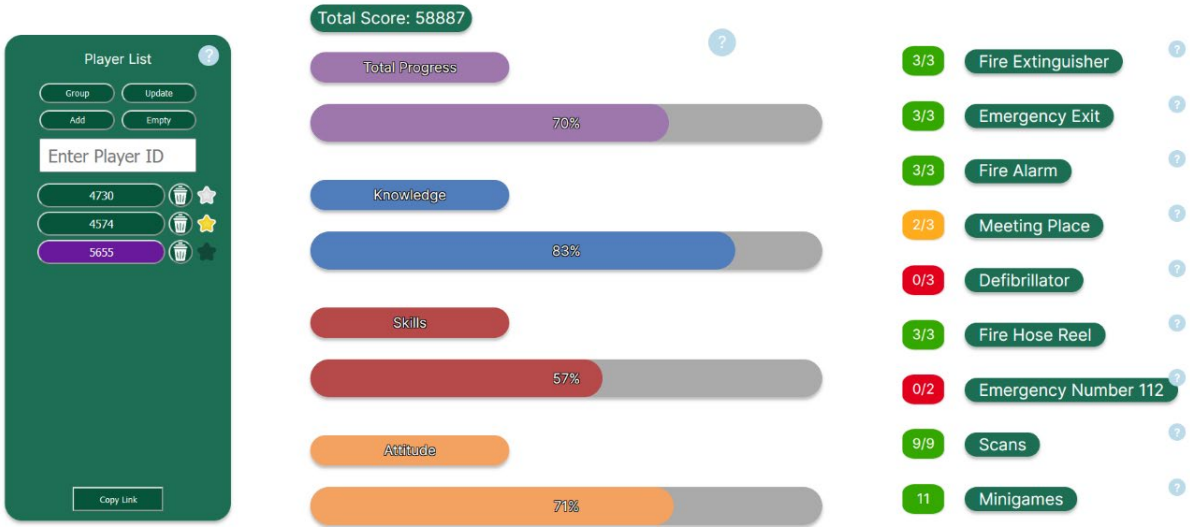

Figure 7. Capture of the online evaluation form for researchers, educators, and parents to visualize the overall progression, achievements, and knowledge of players.

Due to ethical considerations and **GDPR** compliance, the game collects data anonymously. To use this form, you need to know the player's ID number, which can be found in the main screen of the game. The form consolidates data from 114 different actions related to the learning objectives. The gathered data includes key performance metrics, such as the number of actions completed by each player, which can be used to evaluate both game retention and learning-related metrics. The form is designed to present this data in an efficient and easy-to-understand format, offering clear insights into each player's progress and areas for improvement. The tool evaluates these actions and simplifies them into a user-friendly report with the following features:

- **Comprehensive Reporting**: The form generates a detailed report on players' progress, highlighting their strengths but also the areas that require further attention. Teachers can also assess the performance of a group of players, enabling them to evaluate how a class or team of students has progressed together.

- **Alignment with Learning Objectives**: The tool provides four progress bars that measure each player's development in fire-safety knowledge, skills, and attitudes. This allows educators to quickly assess which aspects of fire safety the student has completed, and which areas may need further emphasis.

- **Measurable Outcomes**: The evaluation form also presents eight measurable outcomes that align with the game's primary educational goals. Each outcome is categorized as untouched, partially completed, or totally completed, providing a clear and measurable assessment of the player's learning journey.

- **User-Friendly Interface**: The form was designed with accessibility in mind, making it easy for teachers with varying levels of technological proficiency to navigate, retrieve data, and interpret the results. This was a key consideration in ensuring that all educators could effectively use the tool, regardless of their familiarity with digital tools.

- **Adaptability**: While the form is designed to be intuitive and straightforward, it also offers some flexibility. Teachers can choose to analyze the performance of individual players, small groups, or an entire class, depending on their needs. This adaptability allows the tool to be used in different classroom settings and for various educational purposes.

The online evaluation form has been integrated into the overall Virpa – Fire Expert ecosystem, allowing teachers to track their students' learning outcomes in real-time. We think the development of the online evaluation form was a key milestone in enhancing the game's functionality as an educational tool. By

providing a clear and detailed assessment of players' progress, the tool supports teachers in maximizing the educational value of the game while offering researchers a valuable resource for studying game-based learning.

4.3.7 Backend and Database Integration

In addition to the front-end improvements, WP3 also involved maintaining the game's backend infrastructure to ensure that the AR scanning functionality continued to operate efficiently. The backend was responsible for recognizing fire safety signs and objects in real-time, based on the thousands of images stored in the game's neural network. Any downtime or technical issues with the server affects the game's ability to provide real-time feedback to players scanning signs in their environments. Our tests validated stable conditions with no outages that we could not solve. However, the team recognized that maintaining this infrastructure over the long term will always require ongoing support, and that is bad as the series of Virpa projects ends. Plans were made to continue monitoring and maintaining the backend by current team members to ensure that the game remains operational in the future.

Maintaining an efficient backend system was essential for the continued operation of Virpa – Fire Expert and the associated web tool used for educational evaluation presented in **Section 4.3.6**. The backend updates were designed to support that web tool, which in turn is designed as an independent research tool for anyone, to monitor players' performance and the possible learning outcomes and achieved objectives. The evaluation tool connects seamlessly to the game's database now, updating regularly to present accurate data on player achievements.

4.3.8 Impact on Device Compatibility

The decision to prioritize the AR feature came at a cost: the number of supported Android devices significantly dropped from around 10,000 devices to approximately 1,000 devices. Those are in any case only a small portion of phones used nowadays by kids. These older phones and tablets are unable to comply with the new system and security requirements, which the game is now adhering to. We anticipate that most of the kids in Finland have a phone or tablet that is included in the 1000 supported devices.

The iOS version faced its own set of challenges, which are in any case part of the process when you perform major updates. The update of the game was launched on similar dates for both operating systems.

The annual API level updates imposed by Google remains a looming challenge. Compatibility maintenance over the next five years could require a complete overhaul of the game, especially as Unity versions and mobile platform requirements evolve. A possible sunsetting strategy, where the game gradually becomes unsupported on newer devices over time, was discussed as a long-term solution, as it extends way beyond the time duration of the Virpa3 project.

4.4 Work Package 4: Dissemination and Outreach

Work Package 4 (WP4) comprised all communication activities with relevant stakeholders to enhance the dissemination of the Virpa – Fire Expert game. This section outlines the strategies and methods we implemented. While the email and phone campaigns generated widespread awareness of Virpa – Fire Expert, adoption rates varied. Key obstacles included time constraints within school curricula and limited access to technology. However, personalized follow-ups and school visits significantly boosted engagement and download numbers, with the game being downloaded over 4,600 times by the end of the campaign period.

4.4.1 Marketing and Social Media Campaigns

The multi-channel marketing strategy focused on social media engagement, direct email outreach, and promotional content in key educational publications.

Project and Game Website

The official project website, www.virpagame.fi, has always served as a central hub for information. It has been updated in November 2024 to include all the results and outcomes of Virpa3 project. It is noted here, that unfortunately, the progress evaluation form for teachers and researchers does not scale properly on the version for mobile devices. We expect to solve that situation soon.

Social Media Initiatives

Instagram platform was used to reach primary schools and teachers. After 8 months, the Virpa game profile follows more than 1,000 accounts of schools and educators. A total of 25 feed posts and over 50 Instagram stories were published to gain visibility. Those were about promoting the game's features and sharing fire safety tips. There were sent direct engagement messages to 200 schools and teachers. Overall, with consistent content creation and strategic outreach, the Virpa Instagram account gained over 250 followers including some notable educational institutions. The account will be maintained open, but new content will not be published after 1.1.2025. Regular posts highlighted the key features of the game, presented mini-games, and the AR scanning functionality, or were related to fire safety lessons.

Email outreach campaign

Approximately 3,000 emails were sent to school principals and teachers across Finland during spring, summer and autumn 2024. Contact details were obtained from official municipal websites and it was ensured broad geographic coverage. While initial spring outreach coincided with the end-of-school-year planning, the autumn campaign utilized HubSpot's automation features to improve targeting and delivery.

Phone outreach campaign

During the same period, around 300 follow-up phone calls with school principals were done, seeking to reinforce the email outreach. Despite the challenges of reaching busy school administrators, these calls secured several virtual meetings and provided a direct line of communication for addressing questions and concerns.

Paid marketing content

It was decided to pay for a banner ad on the Opettaja magazine website for the length of one week. We provide information for creating an article about how the game could be integrated in teachers work, but they refused to include on the magazine publications anything related to the game or the outcomes of the ecosystem. Despite the strategic placement of the ad on the magazine website, the campaign did not result in a significant uptick in game downloads.

4.4.2 Direct Outreach to Schools, Fire Departments, and Official Organizations

Direct outreach mainly included in-person school visits and virtual presentations via Teams.

School Visits and Presentations

An email campaign, consisting of 1,200 emails sent to schools, resulted in 112 positive responses and 18 schools committing to integrate the game into their fire safety curriculum. The contact email was designed to be concise, highlighting the game's educational benefits and how it could be effectively integrated as a teaching resource. During the Virpa3 project period, the team conducted visits to 12 schools in Helsinki, Tampere, Turku, Kaarina, Masku, and other small municipalities in the South-West Finland area. During those visits, we consistently observed how well the game engaged children and how enjoyable the learning experience was for them. Additionally, the Virpa environment was presented virtually to the principals of six schools from smaller towns.

Fire Department Engagement

The 21 Finnish fire departments have been consistently contacted throughout the Virpa project series, including Virpa3, to explore collaboration opportunities. For example, during the research by Väittinen and Rosu, seven departments provided direct feedback on the game and participated in a series of interviews. While they generally supported initiatives dedicated to fire safety education, they highlighted the challenges of integrating the Virpa – Fire Expert game into their activities. The departments have long relied on their own materials and prefer more hands-on approaches in their interactions with children and youth.

Outreach to Finnish National Agency for Education Officials

Efforts to engage with the Finnish National Agency for Education (Opetushallitus) aimed to explore potential endorsements or promotions of the game within Finnish schools. These discussions were framed by existing legislation, specifically:

- The Basic Act for Education (Perusopetuslaki, 2016), which mandates a safe learning environment for all children.

- The National Core Curriculum for Basic Education (2014), which specifies the inclusion of fire safety education within health education for grades 7–9 and environmental studies for grades 3–6.

Although Opetushallitus acknowledged the game's relevance to fire safety education, they clarified that they do not have the authority to prescribe specific educational tools. Nonetheless, the conversations provided valuable context for understanding the national educational landscape, including both barriers and opportunities for curriculum integration. Despite the recognized gap in structured fire safety education, achieving nationwide adoption would require sustained efforts and potentially engaging additional educational stakeholders. Officials noted the alignment between Virpa – Fire Expert and national educational goals. Although no formal collaboration was established, the discussions offered a clearer understanding of the complexities of educational governance in Finland and helped inform future dissemination strategies.

Outreach to Siviilipalveluskeskus

Two sessions were held with young civil service members at the Civil Service Center of Finland, Siviilipalveluskeskus, in Lapinjärvi. The idea was to engage young adults performing civil service to introduce the game to schools, should their assignments place them in such environments. Although the sessions were well-received, they did not result in significant dissemination gains. None of the 30 participants from the two sessions were assigned with roles involving working with children in schools.

Outreach to Nouhätä! Campaign

The project team also explored potential collaboration with the Nouhätä! campaign. Nouhätä! logos have consistently been part of the game's visual design, and knowledge has been warmly exchanged about our respective activities. Their program covers students across Finland on a large scale, but, like the fire departments, they have established own procedures and materials, which they prefer to continue using.

4.4.3 Scientific Publications and Participation in National and International Conferences

The research efforts undertaken during the Virpa1, Virpa2, and Virpa3 projects have been highlighted in several national and international publications and conferences. The key scientific outputs from these years are summarized and lightly described later in **Chapter 5**, which also provides direct links to the documents. This section outlines only the publications and conference participations that took place during the Virpa3 project.

- **Title:** *Pedagogic Solutions and Results in Designing a Mobile Game for Fire Safety Teaching*
  Authors: Somerkoski, B., Tarkkanen, K., Oliva, D., Lehto, A., Luimula, M.
  Publication Year: 2022
  Place of Publication: GamiFIN Conference 2022, Levi, Finland
- **Title:** *Virpa-Mobiilipelin Hyödynnettävyys Osana Lasten Ja Nuorten Paloturvallisuusopetusta: Koulujen Ja Pelastustoimen Näkemys*
  Authors: Väittinen, N., Rosu, R.
  Publication Year: 2023
  Place of Publication: Turku University of Applied Sciences, Bachelor's Thesis Series
- **Title:** *Human Factors and Pedagogic Principles to Design a Fire-Safety Pedagogic Game*
  Authors: Oliva, D., Tarkkanen, K., Haavisto. T., Somerkoski, B., Lindberg. A., Luimula., M.
  Publication Year: 2024
  Place of Publication: AHFE Congress, Nice, France
- **Title:** *Impact of synthetic dataset on the accuracy of YOLO object detection neural network*
  Authors: Haavisto, T.
  Publication Year: 2024
  Place of Publication: Turku University of Applied Sciences, Master Thesis Series
- Poster **ITK Congress** in Hämeenlinna on 19–21 March 2023, see **Appendix 2**.
- **Palopäällystöliitto's Seminar on Fire Safety Communication**

  The project team also participated in the Palopäällystöliitto (Fire Chiefs Association) seminars, including the Turvallisuusviestinnän opintopäivät (Safety Communication Study Days) in Hämeenlinna on 23.–24.5.2023. The game was presented to an audience of fire safety professionals, and feedback from participants was positive, with many seeing the game as a potential tool to enhance fire safety training for children. The audience included representatives from key Finnish emergency and rescue organizations, including Etelä-Karjalan hyvinvointialue, Etelä-Savon pelastuslaitos, Helsingin kaupungin pelastuslaitos, Hämeen ammattikorkeakoulu, Hätäkeskuslaitos, Itä-Uudenmaan pelastuslaitos, Kanta-Hämeen pelastuslaitos, Keski-Pohjanmaan ja Pietarsaaren pelastuslaitos, Keski-Uudenmaan pelastuslaitos, Lapin pelastuslaitos, Länsi-Uudenmaan pelastuslaitos, Pelastusopisto, Pirkanmaan pelastuslaitos, Pohjanmaan pelastuslaitos, Porin VPK, Päijät-Hämeen pelastuslaitos, Satakunnan pelastuslaitos, Sisäministeriö, Suomen Pelastusalan Keskusjärjestö, and Varsinais-Suomen pelastuslaitos.

4.4.4 Publications in Specialized Media and Other Types of Appearances

Efforts to gain media coverage and recognition for Virpa – Fire Expert included features in specialized publications and competitions.

- **Pelastustieto Magazine**: An article about the game was published in the November 2024 issue. Two members of the project team authored the article. The magazine is well-known among fire safety and emergency professionals. A capture of the article is presented in **Appendix 3**.

- **eOppimisratkaisu Competition**: The game was a finalist in the Best Finnish Learning Solution competition, with the team presenting the game at the ITK Congress in Hämeenlinna on 19–21 March 2023. The project received a Finalist Certificate from the competition (**Appendix 4**) and gained exposure among educational professionals attending the congress.

- **Podcast and Media Engagement**: In autumn 2023, the team participated in the SeOppiTunti podcast series, hosted by the Finnish eLearning Center. The episode, titled "Oletko turvassa? Digiratkaisut avaimina perehdytykseen ja turvataitoihin," featured discussions about the game's development and its educational impact. The podcast aimed to reach a broad audience and generated positive feedback.

5. Scientific Publications and Contributions

Throughout the Virpa1, Virpa2, and Virpa3 projects, extensive research was conducted to explore and enhance the use of digital and augmented reality tools for fire safety education. This chapter compiles the key scientific publications that resulted from these projects, providing insights into the pedagogical approaches, technological challenges, and empirical outcomes. Each entry summarizes the main contributions and significance of the work.

1. **Title:** *Simulating smoke in a virtual reality application–Case VirPa*
   Authors: Niinikorpi, L.
   Publication Year: 2018
   Place of Publication: Turku University of Applied Sciences, Bachelor's Thesis Series
   Description: This thesis presented the technical aspects of modeling smoke behavior in virtual environments. It detailed the algorithms used to simulate realistic smoke dynamics and discussed their impact on user perception and behavior during fire emergencies.
   Key Contribution: The research significantly improved the realism of the Virpa VR simulator and provided a foundation for creating immersive, behavior-influencing scenarios.

2. **Title:** *Käytettävyysraportti – VR-Teknologia Pelastustoimen Turvallisuusviestinnässä*
   Authors: Somerkoski, B., Oliva, D., Tarkkanen, K., Luimula, M., Lehto, A., Niinikorpi, L.
   Publication Year: 2019
   Place of Publication: Futuristic Interactive Technologies report series, Turku University of Applied Sciences
   Description: The "Usability Report" assessed the implementation of VR technologies in fire safety communication, focusing on the development of a VR application used by emergency services. The study highlights the use of VR headsets to create realistic and immersive training simulations that mimic real-world fire scenarios, particularly emphasizing smoke dynamics and evacuation procedures. The usability of the VR environment was tested using multiple surveys to gather feedback on user experience and learning outcomes.
   Key Contribution: This report provides evidence supporting the use of VR as an effective, engaging tool for fire safety education and communication, particularly for youth and adult audiences. It emphasizes VR's potential in simulating dangerous scenarios, such as smoke propagation, which are difficult or impractical to replicate in real life. The findings contribute to the broader understanding of VR's role in enhancing training and readiness for fire-related emergencies.

3. **Title:** *Virtual Reality as a Communication Tool for Fire Safety – Experiences from the Virpa project*
   Authors: Oliva, D., Somerkoski, B., Tarkkanen, K., Lehto, A., Luimula, M.
   Publication Year: 2019
   Place of Publication: GamiFIN Conference 2019, Levi, Finland
   Description: This publication introduced the initial Virpa VR simulator developed to study human behavior in simulated fire emergencies. The paper detailed how VR was used as a research tool to analyze decision-making processes in different age groups and how environmental factors, such as smoke behavior, affected evacuation strategies.

Key Contribution: The study emphasized the potential of VR for understanding human behavior in fire emergencies and highlighted the need for age-specific educational methods, setting the stage for subsequent Virpa projects.

4. **Title:** *Digital Learning Environments - Constructing Augmented and Virtual Reality in Fire Safety*
   Authors: Somerkoski, B., Oliva, D., Tarkkanen, K., Luimula, M.
   Publication Year: 2020
   Place of Publication: IC4E '20: Proceedings of the 2020 11th International Conference on E-Education, E-Business, E-Management, and E-Learning
   Description: This paper explores the use of VR and AR to create immersive fire safety education tools, demonstrating how these technologies can make learning more interactive and effective compared to traditional methods.
   Key Contribution: The study sets a foundation for future fire safety training innovations with AR and VR, emphasizing the importance of engaging and technology-based learning methods.

5. **Title:** *Research Study Design for Teaching and Testing Fire Safety Skills with AR and VR Games*
   Authors: Tarkkanen, K., Lehto, A., Oliva, D., Somerkoski, B., Haavisto, T. Luimula, M.
   Publication Year: 2020
   Place of Publication: 11th IEEE International Conference on Cognitive Infocommunications – CogInfoCom 2020
   Description: This article explores using AR and VR to teach and test children's fire safety skills. It combines AR for learning fire safety concepts and VR for simulating realistic emergencies, assessing knowledge retention and response.
   Key Contribution: The paper presents a dual approach using AR and VR to make fire safety education engaging and measurable, offering insights into how immersive technologies can improve safety training and evaluate emergency preparedness.

6. **Title:** *Pedagogic Solutions and Results in Designing a Mobile Game for Fire Safety Teaching*
   Authors: Somerkoski, B., Tarkkanen, K., Oliva, D., Lehto, A., Luimula, M.
   Publication Year: 2022
   Place of Publication: GamiFIN Conference 2022, Levi, Finland
   Description: This paper described the pedagogical framework, the design principles, and the empirical outcomes of the Virpa – Fire Expert mobile game. The paper describes the integration of pedagogic theories, such as Vygotsky's constructivist learning model, into game design, ensuring that learning is interactive, engaging, and curriculum-aligned. The work earned the Best Paper Runner-Up Award, showcasing the game's significant potential in educational contexts (**Appendix 4**).
   Key Contribution: The study highlights that AR-based game mechanics, like real-world sign scanning and immersive scenarios, significantly enhance children's fire safety awareness. The empirical results demonstrate improvements in children's recognition and understanding of safety signs. The findings suggest that interactive and authentic game experiences are effective in engaging young learners, offering a promising alternative to traditional, lecture-based fire safety training.

7. **Title:** *Virtuaalista Paloturvallisuutta – Virpa2 loppuraportti*
   Authors: Oliva, D., Somerkoski, B., Tarkkanen, K.
   Publication Year: 2021 (updated in 2024)
   Place of Publication: Turku University of Applied Sciences, Research Archive, Report 297
   Description: This report documented the research methodology used across the Virpa2 project, detailing the design of AR and VR games for fire safety education. It focused on metrics used to assess learning outcomes and the comparative effectiveness of AR vs VR approaches.
   Key Contribution: The project introduced an innovative, technology-based approach to fire safety

education, demonstrating how augmented reality and gamification can effectively engage young learners and enhance knowledge retention compared to traditional teaching methods.

8. **Title:** *Virpa-Mobiilipelin Hyödynnettävyys Osana Lasten Ja Nuorten Paloturvallisuusopetusta: Koulujen Ja Pelastustoimen Näkemys*
   Authors: Väittinen, N., Rosu, R.
   Publication Year: 2023
   Place of Publication: Turku University of Applied Sciences, Bachelor's Thesis Series
   Description: This publication presented a detailed analysis of current fire safety education practices in Finnish schools. Methods included interviews with Fire Departments representatives and primary education schools principals. It identified gaps in the curriculum and opportunities for integrating digital learning tools like Virpa – Fire Expert.
   Key Contribution: Provided valuable insights that guided the dissemination strategies of the Virpa game, aligning it with national educational requirements.

9. **Title:** *Impact of synthetic dataset on the accuracy of YOLO object detection neural network*
   Authors: Haavisto, T.
   Publication Year: 2024
   Place of Publication: Turku University of Applied Sciences, Master Thesis Series
   Description: The work focuses on utilizing synthetic datasets to improve the accuracy and performance of the YOLO object detection neural network, specifically for detecting fire safety signs. The research explores the generation of synthetic images using generative adversarial networks (GANs) for fire safety signs and latent diffusion models for creating realistic background environments.
   Key Contribution: The thesis demonstrates the effectiveness of synthetic datasets in enhancing the performance of object detection models. By automating the creation of synthetic data using GANs and diffusion models, the research showcases improvements in the accuracy and efficiency of YOLOv8, a state-of-the-art object detection network, which has significant implications for fire safety education and emergency response systems. This work highlights the potential of using synthetic data to overcome limitations in real-world data availability and enrich training datasets for machine learning models in safety-critical applications.

10. **Title:** *Human Factors and Pedagogic Principles to Design a Fire-Safety Pedagogic Game*
    Authors: Oliva, D., Tarkkanen, K., Haavisto. T., Somerkoski, B., Lindberg. A., Luimula., M.
    Publication Year: 2024
    Place of Publication: AHFE Congress, Nice, France
    Description: This award-winning paper describes the design and development of Virpa – Fire Expert mobile game, and how human factors of children and educators and five pedagogic design principles were applied.
    Key Contribution: The study demonstrates the effective use of digital gaming, AR, and pedagogic principles to teach fire safety in a captivating way for young learners. It provides a model for integrating real-world interactions into educational games and highlights the potential of using AR to improve learning outcomes in safety education. Furthermore, the research outlines the design considerations and human factors involved, contributing valuable insights into the development of serious games for educational purposes. The work received the Best Paper Award (**Appendix 4**).

11. **UNPUBLISHED.** A scientific research paper was prepared and submitted to Safety Science journal. The paper described at once Virpa1, Virpa2, and Virpa3 projects. The paper has not been yet accepted by

the publisher, but we intend to perform the required changes during the next months, even when that occurs beyond the length of this Virpa3 project. The temporal version of the paper (before corrections) can be found here.

6. Learning Outcomes and Impact Evaluation

The Virpa project series, culminating in Virpa3, has had a notable impact across multiple areas, from enhancing fire safety knowledge among school-aged children to advancing the use of gamified learning in fire safety education. This section provides an analysis of the achieved impacts based on the set objectives and the outcomes realized during the project. The impact assessment, in the form demanded by the funding instrument, is presented in **Appendix 5**.

Acknowledgments

The work performed during the Virpa project series would not have been possible without the help and economic support of Fire Protection Fund, Palosuojelurahasto.

The following persons are very much appreciated too.

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Lasse Pouru
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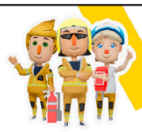
Appendixes

Appendix 1. Created materials for teachers to discuss about fire safety (only in Finnish).



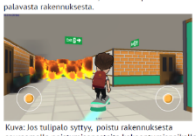
Miksi poistumista pitää harjoitella?

TURKU AMK

- Tulipalon syttymistä ei voi ennakoida.
- Jokaisen rakennuksessa toimivan pitää tietää, miten hätätilanteessa toimitaan

TEHTÄVÄT:
- Tunnetko kaksi eri reittiä pois koulusta?
- Osaatko ulos katsomalla poistumisopasteita?
- Millaisia erilaisia poistumisopasteita olet nähnyt?

Kuva: On tärkeä varmistaa, että kaikki poistuvat palavasta rakennuksesta.



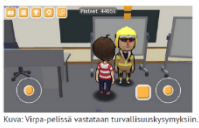
Kuva: Jos tulipalo syttyy, poistu rakennuksesta seuraamalla poistumisopasteita kokoontumispaikalle.

Hätäilmoitus – soita 112

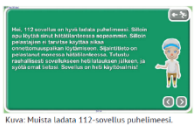
TURKU AMK

Hätäkeskuksen numero on 112.
Hätäkeskukseen soitetaan, kun
- jonkun henki on vaarassa
- kun tarvitset pelastuslaitoksen, poliisin, ambulanssin tai lastensuojelun apua kiireellisesti
- Et tarvitse pin-koodia, mutta ilman virtaa puhelin on hyödytön

Hätänumeroon soitat näin:
1. **Kerro mitä on tapahtunut**
2. **Kerro, missä olet**
3. **Noudata hätäkeskuksen ohjeita ja vastaa kysymyksiin**



Kuva: Virpa-pelissä vastataan turvallisuuskysymyksiin.



Kuva: Mukista ladata 112-sovellus puhelimeesi.

Miten soittaisit hätänumeroon näissä tilanteissa?

TURKU AMK

TEHTÄVÄT: Harjoittele, mitä sanoisit hätänumeroon soittaessasi näissä tilanteissä

112-sovellus

TURKU AMK

Lataa puhelimeesi 112-sovellus. Se on ilmainen!
- Jos olet eksynyt esimerkiksi metsään, sovelluksen avulla pelastajat voivat löytää sinut
- Kun teet hälytyksen sovelluksella, sovellus ilmoittaa sijaintipaikkasi koordinaatit pelastajille

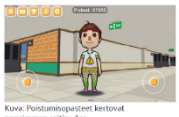
HÄTÄKESKUSLAITOS
NÖDCENTRALSVERKET

Google Play | App Storesta

Poistumisopasteita ja turvallisuuskilpiä

TURKU AMK

- Turvallisuusopasteet ovat kuvia, joilla kerrotaan turvallisesta poistumisesta tai välineistä, joita voi käyttää hätätilanteessa
- Opasteissa käytetään kuvia, jotta lukemiseen ei menisi aikaa
- Kuvia ymmärtävät kaikkialla maailmassa asuvat
- Turvallisuusopasteiden peittäminen julisteella, huonekasvilla tai muulla vastaavalla voi hätätilanteessa vaikuttaa siihen, että kaikki eivät löydä ulos palavasta rakennuksesta



Kuva: Poistumisopasteet kertovat nopeimman reitin ulos.

Kuva: Turvallisuusopasteita ei saa vahingoitta tai peittää.

Paloturvallisuusmerkkejä ja symboleja

TURKU AMK

Punaiset paloturvallisuusmerkit opastavat hätäilmoitus- tai palonsammutusvälineiden luo.
- Turvakilvet tulisi nähdä monesta eri suunnasta mahdollisimman hyvin.
- Uusimmat turvakilvet ovat jälkivalaisevia eli ne näkyvät myös pimeässä.

TEHTÄVÄ:
Kuinka monta erilaisia paloturvallisuusmerkkejä olet nähnyt koulussasi?

Poistumisopaste → Exit-kilpi

TURKU AMK

Vihreä poistumisopaste on kilpi, jota käytetään uloskäytävän sijainnin ja poistumiseen käytettävän kulkureitin osoittamiseen.
- Poistumistiet on merkitty vihreillä poistumiskilvillä, joissa on poistumissuuntaa osoittava nuoli.
- Useat turvallisuuskilvet ovat jälkiheijastavia – ne toimivat hetken aikaa myös pimeässä

POHTIMISTEHTÄVÄ: Mitä reittiä poistuisit, jos kouluusi tulisi palohälytys?

Kuva: Palotilanteissa ja palonharjoituksessa pitää poistua ulos kokoontumispaikalle nopeasti mutta rauhallisesti.

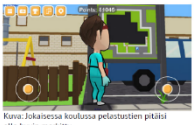
Kuva: Turvallisuuskilvet ovat jälkiheijastavia, siis ne voi nähdä myös pimeässä.

Pelastustie

TURKU AMK

Pelastustie on ajotie, jota käyttäen hälytysajoneuvot pääsevät hätätilanteessa riittävän lähelle rakennusta.
- Pelastustielle ei saa pysäköidä autoja, kasata lunta eikä mitään muutakaan liikennettä estävää

TEHTÄVÄT:
- Missä olet nähnyt pelastustie-liikennemerkin?



Kuva: Jokaisessa koulussa pelastustien pitäisi olla hyvin merkitty.

Kuva: Virpa-pelissä paloauto pääsee lähelle rakennusta palonharjoitus-tehtävässä.

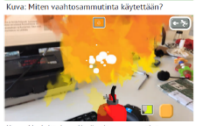
Käsisammutin-opaste

TURKU AMK

Käsisammuttimia voi käyttää pienten tulipalojen sammuttamiseen.
Kaikki käsisammuttimet toimivat samalla periaatteella:
1. irrota sokka
2. ota kiinni letkun päästä
3. sammuta 3 - 5 metrin etäisyydeltä - tähtää liekkien alaosaan - sammuta lyhyin suihkauksin

Käsisammuttimen sisällä on sammutusjauhetta, hiilidioksidia tai sammutusnestettä.
Yhdestä sammuttimesta sammutusainetta riittää vain alle minuutin ajan.
Koulussa käsisammuttimia on ulko-ovien vierellä, seinillä tai sammutinkaapeissa.
Jos et jaksa nostaa sammutinta, et voi käyttää sitä.

Kuva: Miten vaahtosammutinta käytettäisiin?

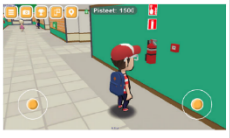


Kuva: Harjoittele pelissä miten sammutinta käytetään.

Paloilmoituspainike

TURKU AMK

Paloilmoituspainike on automaattisen paloilmoittimen osa.
- Painikkeesta painamalla hätäkeskus saa ilmoituksen tulipalosta.
- Painikkeessa on usein suojalasi tai kansi, jonka alla olevasta napista hälytys tehdään.
- Hälytys on hyvä varmistaa soittamalla 112 turvallisesta paikasta.



Kokoontumispaikkamerkki

TURKU AMK

Kokoontumispaikkamerkin luokse kokoonnutaan silloin, kun koulussa on annettu käsky poistua ulos rakennuksesta.
Oppilasryhmät kokoontuvat merkille hätätilanteessa ja aikuinen tarkistaa, että kaikki ovat päässeet pois rakennuksesta.

Tämän vuoksi kaikkien on jäätävä merkin luokse, kunnes muita ohjeita annetaan.

TEHTÄVÄ:
- Tiedätkö missä kokoontumispaikkamerkki on koulussasi?
- Oletteko sopineet opettajan kanssa minne mennään hätätilanteessa

Kuva: Virpan koulussa kokoontumispaikka on pihalla pallokentän vieressä

Defibrillaattori

TURKU AMK

Defibrillaattori, eli deffa tai sydäniskuri, on ensiapulaite, jolla voidaan käynnistää pysähdyksissä oleva sydän sähköimpulssin avulla.
- Defibrillaattoreitta on ostoskeskuksissa, kouluissa ja muissa yleisissä paikoissa
- Kun laite avataan, laite kertoo kuuluttamalla, miten tulee toimia. Idea on, että kuka tahansa voi käyttää sitä hätätilanteessa

TEHTÄVÄT:
Tiedätkö missä defibrillaattori on sinun koulussa?

Kuva: Oppilaat pelastivat kaverinsa sydäniskurilla. Tositapahtuman uutinen Virpa Sanomissa

Kuva: Virpa-pelin virtuaalikouluun on hankittu defibrillaattori.

Appendix 2. Poster published in ITK Conference.

Appendix 3. Capture of article published in Pelastustieto magazine.

PALOTURVALLISUUS

Paloturvallisuusoppia kännykällä

Paloturvallisuutta voi oppia myös kännykällä. Seikelän koulussa Maskussa oppilaat perehtyvät innostuneesti kännykkä kädessä paloturvallisuuteen.

Kuutosluokkalainen **Miina Leskinen** pitää peliä hauskana ja opettavaisena.

”Sammutusminipeli oli ehdottomasti paras osa. Olen mukana VPK:ssa, joten osaisin oikeastikin sammuttaa palon”, hän kertoo innostuneesti.

Kolmasluokkalaiset **Valtteri Nummela** ja **Minea Ekman** kehuvat peliä.

”Oli helppo pelata, hahmoa oli helppo ohjata”, Valtteri kiittelee.

”Aluksi hahmon ohjaaminen oli hankalaa, mutta kun siihen tottui, se oli helppoa”, Minea kertoo.

Kolmannen luokan opettaja **Marjo Tuomela** pitää peliä mielenkiintoisena tapana oppia.

”Peli oli tosi innostava oppilaille, eikä siinä ollut mitään ikäviä asioita. Tekemällä oppiminen jää paremmin mieleen.”

Virpa2-hankkeen tavoitteena oli kehittää uusia tapoja opettaa paloturvallisuutta. Lopputulos on ilmainen digitaalinen pedagoginen oppimisympäristö, mobiilipeli Virpa-palomestari. Se hyödyntää lisättyä todellisuutta ja konenäköteknologiaa interaktiivisen oppimiskokemuksen luomiseksi.

Paloturvallisuuteen liittyvän opetuspelin suunnittelu oli monialaisen yhteistyön tulosta. Siihen osallistuivat muun muassa palotarkastajat **Nenna Muurinen** ja **Kari Kummunsalo** Varsinais-Suomen pelastuslaitokselta sekä vastuualuejohtaja **Mikko Puolitaival** Satakunnan pelastuslaitokselta. Turvallisuuspedagogiikan dosentti **Brita Somerkoski** vastasi pelin pedagogisesta sisällöstä. Tekninen suunnittelutiimi koottiin Turun AMK:n Tulevaisuuden Interaktiiviset Teknologiat -tutkimusryhmän teknologeista ja opiskelijoista. Peliä kehitettiin todellisuutta hyödyntämällä ja sen pohjalta, miten ihmiset käyttäytyvät palotilanteessa.

Pelissä käytetään puhelimen tai tabletin kameraa oikeiden paloturvallisuusmerkkien ja -objektien skannaamiseen ympäristöstä, esimerkiksi omasta koulusta.

Pelissä pelaaja on kolmekerroksisessa koulurakennuksessa, jossa hän kohtaa paloturvallisuuteen liittyviä tehtäviä ja haasteita. Pelaaja voi harjoitella poistumista, ja lisää haastetta saadaan, kun peliympäristöstä otetaan valot pois. Pelaaja ratkaisee liitutauluille piirrettyjä pulmia, vastaa luokkahuoneissa palomestarien esittämiin kysymyksiin, etsii erilaisia vaaroja ja pelaa minipelejä, joissa turvallisuus on keskeinen aihe. Pelissä korostetaan erityisesti lisätyn todellisuuden teknologian hyödyntämistä. Pelissä käytetään puhelimen tai tabletin kameraa oikeiden paloturvallisuusmerkkien ja -objektien skannaamiseen ympäristöstä, esimerkiksi omasta koulusta. Tämä yhdistää pelin virtuaalisen maailman todelliseen maailmaan ja tekee oppimiskokemuksesta elävän. Peli soveltuu erinomaisesti pelattavaksi koulurakennuksen sisällä esimerkiksi terveystiedon tunneilla. Pelissä ansaitaan pisteitä skannaamalla koulurakennuksen turvakilpiä. Tutkimuksen perusteella huomattiin, että pelillistäminen monipuolisti paloturvallisuuskasvatusta ja turvallisuusviestintää.

Pelin rinnalle luotiin PowerPoint-esitys opettajien käyttöön. Ideana siinä on, että opettajat antavat oppilaidensa pelata peliä kouluaikana. Pelin tapahtumiin palataan muutaman viikon jälkeen, ja oppilaat voivat kertoa pelikokemuksistaan ja siitä, mitä ovat oppineet.

Virpa on toteutettu Palosuojelurahaston tuella. ■

Teksti: David Oliva ja Tony Halme, Turun Ammattikorkeakoulu, **kuva:** Tony Halme. Kaikki peliin liittyvät materiaalit löytyvät osoitteesta: www.virpagame.fi.

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Appendix 4. Awards and recognitions

Appendix 5. Impact target table

	Palosuojelurahaston valtakunnallinen vaikuttavuustavoite 2013	Vaikuttavuustavoitteeseen liittyvät haasteet	Hankkeelle asetettu vaikuttavuustavoite	Tavoitteeseen liittyvät strategiset painopistealueet	Konkreettiset toimenpiteet tavoitteen saavuttamiseksi ja niiden toteutusajankohta	Mittarit, seurannan välineet/tavat, tietolähteet sekä mittaustulosten näkymisen aikajänne
1.	Onnettomuuksien ehkäisy on tehostunut ja asumisen paloturvallisuus parantunut.	Fire safety teaching is enhanced with new technological solutions, such as the Virpa – Fire Expert mobile game, which is a digital learning environment for mobile devices. Creative and effective teaching materials and methods are provided to key personnel in rescue services and to primary school environmental and health education teachers to advance fire safety education. The situation was partly confirmed during the project, e.g., work by Väittinen and Rosu (Sections 4.1.1 and 4.1.2), who interviewed school principals and fire departments. Fire safety should be taught in schools, but the education is not coordinated, and each school approaches fire safety in its own way, or not at all. Fire Departments have their own methods, which were not analyzed in this project.	Primary school children across Finland learn and understand fire safety and accident prevention measures better. The necessary knowledge, skills, and attitudes are accessible to every child. The developed game Virpa - Fire Expert is an interactive and engaging digital learning environment for learning fire safety. The game was improved to make it more accessible, and an additional online evaluation tool was created for teachers to support education. The game focuses on risk control and fire safety through various minigames and hazard identifications (see Section 3.2). The project aimed to increase the number of users and downloads, thereby expanding the impact of the three Virpa projects: Virpa, Virpa2, and Virpa3 (Section 4).	Fire safety teaching is enhanced with new technological solutions, such as the Virpa – Fire Expert mobile game, which is a digital learning environment for mobile devices. Creative and effective teaching materials and methods are provided to key personnel in rescue services and to primary school environmental and health education teachers to advance fire safety education. 1. General improvements were made to the game to make it more accessible, such as adding text-to-speech and offline modes (Sections 4.3.2, 4.3.3, and 4.3.5). 2. The game's availability in app stores was ensured by upgrading to new API levels and dependencies (Section 4.3.1). 3. Efforts were made to engage schools and teachers more effectively (Section 4.3.6). 4. Outreach efforts to the Finnish National Agency for Education were carried out (Section 4.4.2).	The needs of rescue services and schools for teaching fire safety will be identified through interviews (autumn 2022) and a workshop (winter 2022). Game analytics will be examined to determine how playtime and in-game actions correlate with actual learning. Information about the existence and functionalities of the digital learning environment will be more effectively communicated to key personnel in rescue services, school principals, and teachers (spring 2023). 1. The game was made more accessible for younger kids with reading difficulties through text-to-speech functionality (Section 4.3.2). An offline mode was also added (Section 4.3.3). 2. Updates were made to meet new API levels and ensure the game's continued availability in app stores (Section 4.3.1). 3. An online evaluation tool for teachers was developed to support education and made available on the project's website (Section 4.3.6). 4. Over 1,200 emails were sent to school principals (Section 4.4.2). 5. A social media campaign on Instagram engaged schools (Section 4.4.1). 6. The website was updated to include the latest materials, including the online evaluation form (Sections 4.4.1 and 4.3.6). 7. Interactive school visits were conducted on a small scale (Section 4.4.2).	The current state of fire safety education in schools and through rescue services will be mapped. Rescue services and schools will be made aware of the digital learning environment and will incorporate it into their activities. Communication efforts will consider the needs and practices of the target group, and new materials will be provided more efficiently with these considerations in mind. 1. Game downloads now exceed 4,600. Metrics related to player actions show retention rates and the use of the real-world sign scanning feature (Section 4.2.1). 2. Overall analysis of specific research interventions in schools, such as fire safety knowledge assessments before and after gameplay (Section 4.2.2). 3. An online evaluation form was created to assist educators in achieving teaching goals (Section 4.3.6).
2.	Tietämys paloturvallisuusasioista on lisääntynyt. Yhteisöt ja yksityiset ihmiset ottavat turvallisuusasiat huomioon jokapäiväisessä toiminnassaan	Fire safety communication is technical and boring. It is difficult to get young people interested in the topic. Children lack basic knowledge and necessary skills, such as understanding the dangers of smoke or how to respond in different emergency situations. The situation was partly confirmed during the project, e.g., work by Väittinen and Rosu (Sections 4.1.1 and 4.1.2), who interviewed school principals and fire departments. Fire safety should be taught in schools, but the education is not coordinated, and each school approaches fire safety in its own way, or not at all. Fire Departments have their own methods, which were not	Young people become interested in fire safety by playing an innovative and attractive game. Through gameplay, children gain knowledge, skills, and attitudes. After playing, they know how to consider safety in schools and in their everyday activities. 1. Results confirmed that players found the game engaging. Retention rates were high, despite the game being an educational mobile app for children (Section 4.2.1). 2. Results confirmed the pedagogical impact of the game in teaching about fire safety signs in real-world settings (Section 4.2.2).	Fire safety knowledge and learning are made more interesting and engaging than before. The project ensures that the created learning environment reaches as many schoolchildren in Finland as possible. 1. Efforts were made to improve engagement with schools and teachers (Section 4.3.6). 2. Outreach activities included engagement with the Finnish National Agency for Education (Section 4.4.2).	The created digital learning environment is improved based on collected experience (autumn-winter 2022). The functionality for scanning safety signs is presented more clearly in the game. A multiplayer option is added so that young players can play and solve game tasks together. 1. A social media campaign on Instagram aimed to engage schools and relevant safety organizations (Section 4.4.1). 2. The project website was updated to provide the latest materials, including the online evaluation form (Sections 4.4.1 and 4.3.6). 3. Interactive school visits were conducted on a small scale (Section 4.4.2). 4. The final report of Virpa3 was sent to all Finnish Fire Departments. 5. Outreach activities targeted the Finnish National Agency for Education, the Civil Service Center of	The functionality and educational value of the product have already been verified through initial usability studies. The key metrics now are the number of downloads, playtime, and usage rate. The goal is 30,000 downloads within four years. 1. The total number of downloads, now over 4,600, is still far from the overall goal after four years. However, technical efforts were made to ensure the game is usable on most mobile phones and easily discoverable in app stores (Sections 4.3.1, 4.3.5). 2. The online evaluation form has not been live long enough to verify teacher engagement levels.

		analyzed in this project.			Finland, and NouHätä! (Section 4.4.2), as well as the Fire Officers Association (Palopäällystöliitto) (Section 4.4.3). 6. Paid marketing content appeared in the Finnish Teacher magazine (Section 4.4.1). 7. The game was featured in specialized media, such as Pelastustieto magazine (Section 4.4.2).	However, we believe it will aid teachers in using the game more effectively (Section 4.3.6). 3. Ten scientific documents were published in various congresses or as final theses during the Virpa project series.
3.	Pelastustoimella on hyvä palvelukyky: ▪ hyvä turvallisuuskulttuuri, ▪ vähemmän onnettomuuksia, ▪ pienemmät vahingot, ▪ nopea ja tehokas apu onnettomuuksissa sekä ▪ hyvä yhteistyö.	Not all operational situations can be practiced under realistic conditions, and rescue services lack the best pedagogical or communication tools for engaging with children.	The developed product offers new opportunities and functionalities for rescue services in teaching fire safety. Children enjoy playing games, so it is essential for rescue services to have modern communication tools that are tailored to their target audiences. Enhance the operational capability of rescue services by providing modern and interactive tools that improve children's fire safety knowledge and support collaboration with schools and communities.	The operational capability of rescue services remains strong in changing environments. The teaching methods and needs of rescue services are mapped to enable better fire safety education through the game.	The needs of rescue services and schools for fire safety education are identified through interviews (autumn 2022) and a workshop (winter 2022). Awareness of the created digital learning environment and its functionalities is more effectively communicated to key figures in rescue services and school principals and teachers (spring 2023).	Through usability studies (TP2), it is possible to understand how effective teaching can be provided by rescue services using the new innovative solution. At the end of the project, it will be determined how rescue services have adopted the offered opportunity.
		The challenge still lies in offering innovative and effective materials to fire safety organizations to facilitate the implementation of engaging activities with children.	1. The game gives rescue services new ways to engage children in learning fire safety. This modern tool is specifically designed to increase knowledge and awareness through interactive methods (Sections 4.3 and 4.4). 2. Workshops and presentations were held to showcase the educational benefits of Virpa – Fire Expert and promote its use among fire safety professionals (Section 4.4.3).	1. Efforts were made to improve engagement with fire safety organizations (Sections 4.4.1 and 4.4.3). 2. The project identified specific training gaps and addressed them by providing digital and interactive learning tools (Section 4.4.2).	1. Over 1,200 emails were sent to school principals (Section 4.4.2). 2. A social media campaign on Instagram was launched to engage with schools (Section 4.4.1). 3. The website was updated to provide the latest materials, including the online evaluation form (Sections 4.4.1 and 4.3.6). 4. Interactive visits to schools were conducted on a small scale (Section 4.4.2). 5. The final report of Virpa3 was sent to all Finnish Fire Departments. 6. Outreach efforts included the Finnish National Agency for Education, the Civil Service Center of Finland, NouHätä!, and Palopäällystöliitto (Sections 4.4.2 and 4.4.3). 7. Paid marketing content was published (Section 4.4.1). 8. The game was featured in specialized media, such as Pelastustieto magazine (Section 4.4.2).	1. The usability study conducted provided insight into how effective the game is as an educational tool for rescue services. Metrics on engagement and feedback from workshops helped gauge the game's impact (Sections 4.2.1 and 4.4.3). 2. Continued efforts were done to facilitate integration of the game into more rescue service training programs (Section 4.4.3).

4.	Osaavan henkilöstön riittävyys ja saatavuus varmistetaan: pelastushenkilöstön mitoituksen perusteet, rakenne ja suorituskykyvaatimukset on tarkistettu. Pelastustoimen koulutusjärjestelmä takaa myös vapaaehtoisten ja sivutoimisten palokuntien pelastushenkilöstölle yhtenäisen koulutustason. Tarvelähtöinen työterveys- ja työturvallisuustoiminta tukee henkilöstön työhyvinvointia koko työuran ajan.					
5.	Tutkimus- ja kehittämistoiminta tuottaa riittävästi toimialan kehittämisessä ja toiminnan kohdentumisessa tarvittavaa tietoa.	Rescue services do not have enough personnel capable of developing and producing future solutions related to interactive technologies. Game development is expensive. Game developers operate separately from the systems of rescue services. Research and development results do not always effectively transition into practice or are not readily accessible. 1. The project aimed to bridge the gap between game developers and rescue services by ensuring that the developed solution aligns with the needs and capabilities of fire safety professionals (Sections 4.3 and 4.4). 2. Challenges remain in ensuring research findings are implemented practically, but workshops and collaboration sessions were a step forward in improving this integration (Section 4.4.3)	New technology is used in rescue services, which enhances operations during fire incidents and creates opportunities for future development. The game has been developed in collaboration with rescue services. The new research and development project will precisely verify how effectively different fire safety knowledge, skills, and attitudes are taught. Generate research data on the effectiveness of game-based learning environments in teaching fire safety and make the research findings available to a broader audience. 1. The game has provided a platform for fire safety professionals to use innovative technology for educational purposes, and future research will continue to evaluate its effectiveness (Sections 4.2 and 5). 2. Collaboration with rescue services has ensured the game meets real-world needs, and research results have been shared at conferences and in academic publications (Section 5).	The completed product leaves players with an understanding of the dangers of fire. The project verifies and evaluates the learning experience achieved through each game feature. 1. The learning outcomes of each feature in the game were evaluated, with data showing an increased understanding of fire hazards among children (Section 4.2). 2. Publications and conference presentations have disseminated the results widely, and feedback from participants confirms the educational value of the game (Section 5).	An updated version of the VirPa game will be produced, including an evacuation drill game designed for school environments and a digital safety walk feature. The game will be tested in communication activities of rescue services in schools for primary school students. Game data and analytics will be analyzed to improve the Virpa game and other educational games. 1. Updates to the game included new features such as evacuation drills and safety walks, tested in collaboration with schools and fire departments (Sections 4.3.4 and 4.4.2). 2. Game analytics have been analyzed to provide insights for future improvements and to guide the development of educational features (Sections 4.2 and 4.3).	The research will result in at least one bachelor's level engineering thesis, one scientific article, and one conference paper. 1. Ten scientific documents have been published in conferences or as final theses during the Virpa project series (Section 5). 2. During the Virpa3 project, two conference papers, one bachelor's thesis, and one master's thesis were completed. 3. A scientific article summarizing the outcomes of the Virpa project series has been prepared and submitted to Safety Science journal. Although not yet accepted, the team is committed to making revisions for publication, even after the official project conclusion (Section 5). 4. The game and its findings have been featured in specialized media such as Pelastustieto (Section 4.4.4). 5. The project was recognized as a finalist in the eOppimisratkaisu competition (Section 4.4.4).