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Virtual Reality as an Educational Tool in the Training of Explosives for the Swedish Armed Forces Personnel

Anthony Colton
Sebastian Säbom

Faculty of Computing, Blekinge Institute of Technology, 371 79 Karlskrona, Sweden

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The authors declare that they are the sole authors of this thesis and that they have not used any sources other than those listed in the bibliography and identified as references. They further declare that they have not submitted this thesis at any other institution to obtain a degree.

Contact Information:
Author(s):
Anthony Colton
E-mail: a.w.colton@gmail.com

Sebastian Säbom
E-mail: sabom.sebastian@gmail.com

University advisor:
Dr. Ahmad Nauman Ghazi
Department of Software Engineering

Co-advisor:
Dr. Salam Mohammed
Research Director
Swedish EOD and Demining Centre (SWEDEC)
Swedish Armed Forces

Faculty of Computing
Blekinge Institute of Technology
SE–371 79 Karlskrona, Sweden

Internet : www.bth.se
Phone : +46 455 38 50 00
Fax : +46 455 38 50 57

Abstract

Virtual reality (VR) is not part of the curriculum of explosives for the Swedish Armed Forces (SAF) today. According to the research department at the Swedish EOD and Demining Centre (SWEDEC), this study is the first step in introducing VR to modernize the educational system for explosives within the SAF.

This study investigates the perceived obstacles to why VR is not used as a complement in the education of explosives for the SAF and finds the potential benefits and risks of implementing it. Qualitative data was collected through the survey method 'case study research' where experts in the field of explosives tried a VR prototype made specifically for this study before being interviewed. Thematic analysis was used to analyze the results from the interviews.

This study shows that VR is not part of the curriculum of explosives today because the older generation who decides either has a reluctant mindset or lacks the knowledge and awareness to see what it has to offer. The interviewees agree on the potential benefits of implementing VR in this field, the main benefits are cost reduction, safety, and logistics. If the quality of the program is poor, the safety aspect and learning behaviors could be jeopardized because a user is treating the program like a game

To implement VR as a complement in the education of explosives for the SAF has more potential benefits than potential risks, and the potential risks can be reduced by using a program with quality assurance. There is an overwhelming interest among the interviewees where all participants agree that the education in explosives could benefit from implementing VR.

Keywords: Virtual reality, educational tool, military training

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Contents

Chapter 1

Introduction

This study investigates the potential benefits and the potential risks of implementing Virtual Reality as a tool in the education of explosives for the SAF, and also what the perceived obstacles are to adopting this kind of program to the education of explosives for the SAF. It could be considered a modern approach to digitalize the education of explosives to potentially reduce costs, effectivize logistics and reduce security risks.

Studying in an old-fashioned way by attending classroom lectures to solely watch and listen can be linked directly to boredom [7] [10]. When students get bored their motivation and interest decreases [7] [10]. In a study about students getting bored of science, it was found that if the subject becomes tedious and dull, their interest can disappear completely [7]. To kindle their interest the subject needs to be engaging, preferably practical where the student should be given the opportunity for exciting and varied experimental and investigative work [7]. It is enough that students are bored and lack the likeability of the subject for their academic achievements to possibly be affected negatively [10]. The theory phase for learning a new explosive in the SAF is similar to the school system consisting of reading and power-point presentations. This could be modernized with virtual reality to potentially heighten the interest, motivation, and likeability of the students in this phase. If students are more engaged and interested in the subject and thus learning more, the safety aspect when using the live explosive might be affected positively.

A problem for students when practicing a skill is the lack of instant and constant feedback [12]. Virtual reality can be a great tool for students learning experience [12]. With virtual reality, students can get instant and constant feedback and they can evaluate themselves and thus get better [12]. With this approach, a student can get more effective and confident in the area they are practicing to enhance their skills [12].

1.1 Background

Meta's Oculus [1] explains that virtual reality (VR) has "cutting-edge graphics, best-in-class hardware, and artistically rendered experiences.." to fully emerge the user in the realistic 3D worlds using specially designed 3D glasses.

Swedish EOD and Demining Centre (SWEDEC) mention that VR is used for other areas in the SAF, but is mostly vehicle-related. With this study, SWEDEC can get a better understanding of why VR for educational purposes for explosives, is an area that should be investigated further.

Currently, VR is not part of the curriculum of explosives for the SAF. According to the research department at SWEDEC, this study is the first step in introducing VR to modernize the educational system for explosives within the SAF.

Using live explosives during training can be considered a lengthy process from the planning phase to the execution phase. The army unit must take into consideration permissions, transport procedures, block off practice areas, and then undergo a series of safety demonstrations and measures before using live explosives. With this whole process, the individual will still get a limited understanding of the explosives. The digitized tools can limit this process, lower the cost and heighten the understanding of the explosives.

The curriculum for hand grenades is structured in steps by first learning theory about the specific grenade before practicing with a grenade not containing explosives and finally using a live grenade. An exam for the theory needs to be passed before proceeding to the next step. To pass this exam the personnel must read and attend lectures. This process could potentially be modernized by implementing VR so the theory can be visualized.

1.2 Contribution

This study aims to investigate if VR can be introduced as a natural next step between theory and using live explosives or in other words, a complement to the education of explosives for the SAF. Within a digitized environment, the personnel can be creative within the limit of the software rules which are dynamic and can expand.

This study can be used as a foundation for further research or as an argument by SWEDEC when discussing implementations of VR for educational purposes for explosives.

1.3 Scope

Conducting research for the SAF with the term ‘explosives’ creates a scope that is too broad. In the term ‘explosives’ there are multiple weapons involved, such as different mines, hand grenades, grenade launchers, etc. To limit the scope, this research will focus on hand grenades and analyze the findings to assume if VR can be used to complement the education of other explosives. Focusing on hand grenades makes it easier to find participants to be part of the study because in the SAF all personnel who completed the basic military training have been taught the theory and usage of hand grenades. This means that officers are more likely to have the skills necessary to educate in this type of ammunition.

1.4 Outline

To obtain the data for this research, individual interviews will be conducted with Army personnel who has experience with hand grenades. The level of expertise in hand grenades varies among the participants where the minimum required experience is to have undergone hand grenade education and been certified by the SAF.

A prototype for VR is created by the authors where the user can move around, see/move their hands to pick up hand grenades to throw or place anywhere. When a grenade detonates the user can observe its effect on the dummies which represent humans placed inside the virtual space.

This prototype is used as a guideline for each participant to get a better understanding of the questions they will be answering individually. The answers from each participant are analyzed and compared to each other to find common thoughts and anomalies.

Chapter 2

Related Work

2.1 Education with VR related to combat

Fan and Wen [8], conducted a study to find if VR can be used as a tool for soldiers to gain combat experience confined in a safe environment. In this way, their supervisor can observe and assess the soldier's actions and give feedback for improvements [8]. Soldiers in one, three, and six-man teams conducted a hostage rescue mission in VR where their times were compared with other teams of the same size. The teams that were compared either consisted of all members being experienced or no members being experienced in conducting rescue missions. The result shows that the experienced groups had better results in all areas. VR, when being realistic, becomes relatable to real life and thus, experience and skills can be brought through the barrier between software and real-life [8].

Modern militaries are increasing their interest and investments in VR technologies [3]. VR cannot replace specific training such as physical or operational training but could still benefit other areas and in turn, be cost-effective and have technological advantages [3]. VR is in rapid development, and its importance will most likely increase [3].

2.2 Education with VR related to safety

The construction industry can be a dangerous place to work because it has the most significant number of preventable fatalities [11]. When training individuals for their new task within this industry, they could instead use VR to mitigate the dangers which exist until they have the skills necessary to be able to perceive potential dangers [11]. The results show that the group which trained to perceive dangers with the help of a 'Personalized Guidance VR Training' got better at perceiving potential dangers compared to the other groups that used 'Free Exploration VR Training' or 'Slides Training' [11].

Similar to this study, another study comes to the conclusion that safety hazards can be learned to identify through the use of VR before entering the actual workspace [17]. To get a better effect of this training, the trainee can practice only on particular tasks where only certain risks are present [17]. By selecting to practice with only relevant hazards and scenarios, the trainee can prevent an overload of information [17].

2.3 Education with VR related to likeability

A study that explores the usability and likeability of VR games for educational purposes concluded that VR could provide highly motivated software and, therefore, could achieve better effects than other software [14].

To use of VR games for educational purposes showed that students who previously had poor performances due to boredom or other distractions now showed more interest in the subject [15]. This environment creates an extra motivating drive in the student to attract their attention [15].

It is beneficial to use VR in the education of mathematics for a student in primary school [16]. Seventy-eight percent of the students believe it's most suitable when simulating operation experience and understanding principles, and more than half of the students got their interest in the subject significantly increased [16]. Because the student, together with their teacher, can completely immerse into a virtual environment, the student can observe concrete things and thus easier understand abstract concepts and mathematical models [16]. There was a similar study conducted with students in fourth grade using VR to learn mathematics and came to the same conclusion [4]. The students, with the help of VR, would increase their academic achievements and maintain the level of student engagement in mathematics and thus be more effective than with their normal curriculum [4].

Chapter 3

Method

3.1 Research questions

This study answers three research questions.

RQ1: What are the potential benefits of using Virtual Reality as a complement in the education of explosives within the Swedish Armed Forces?

RQ2: What are the potential risks of using Virtual Reality as a complement in the education of explosives within the Swedish Armed Forces?

RQ3: What are the perceived obstacles to the adoption of VR for explosives education within the SAF?

3.2 NadEm - Virtual learning application

NadEm is a 3D simulator used as a virtual learning application explicitly created to be used for this empirical study. The purpose of NadEm is to help each participant get a better understanding of the interview questions. It contains basic functionality and limited graphics but enough for the interviewee to understand what should be conveyed. Without this tool, there was a risk that participants wouldn't have understood the possibilities VR has to offer and thus miss-interpret the interview questions. Even if participants would understand each question without NadEm, their answers could still be limited because their answers wouldn't be based on related experience. The consensus is that NadEm was needed to get more reliable data from the interviews.

3.2.1 Test dummies

A test dummy represents a human who is 175cm tall and weighs 75kg. The observable effects from detonated hand grenades on the test dummies in NadEm are limited to getting feedback on how many fragments have hit the individual test dummies and observing the pressure wave created by the detonation pushing the test dummies back.

- Fragments
  - Shrapnel will hit surrounding test dummies based on logic och calculations. An example is that a test dummy that is blocked by something will not get hit by shrapnel. If shrapnel hits a test dummy, it will "die", and above its head, a canvas will appear with information about the shrapnel hits on that specific test dummy. The canvas displays three columns; 'Body Part', 'Shrapnel hits', and 'Distance'. The 'Body Parts' are divided into the head, upper body and lower body. The 'Shrapnel Hits' presents the number of shrapnel that body part was hit by and 'Distance' presents the distance from the hand grenade during its detonation phase to the specific body part.
- Pressure wave
  - The participant can observe the pressure wave created by the explosion through a push-back effect it has on the close surrounding test dummies.

3.2.2 Participant experience

When starting a new session of NadEm, the participant puts on an Oculus Quest 2 headset and straps the respective hand controllers to their wrists. When the simulation starts, they find themselves in the middle of the simulated environment. They can look around at the environment and make gestures with their hands which is the only body part that is visible. Moving is done by either using the controller or physically moving. They can follow their choices freely with limited restrictions.

The participant can pick up a hand grenade, use it by pulling the pin, and release the grenade wherever they want in the environment. When the hand grenade explodes, each test dummy who was within the area of effect for the pressure wave or who was hit by shrapnel will fly/fall over and display information about the shrapnel hits. During a session, the participants are in complete control of possible actions, including restarting the simulation session.

3.2.3 Environment

The simulation area is a roofless room with a size of approximately 100x100 meters. Located in this room, there are test dummies placed in different scenarios, such as different army formations and an area to simulate UO (Urban Operations) with walls and windows. The hand grenades are placed on boxes that are placed to be easily accessed from all scenarios. The floor has a material attached to it that represents a grid, with each grid box being 1x1 meter to make it easier to determine distances.

3.2.4 Hand Grenade

The implemented hand grenade used by the participant has the real qualities of the Swedish hand grenade 2000 (SHGR2000). This specific hand grenade has a kill zone up to five meters from the grenade, and damage from single shrapnel can occur up to 50 meters. This prototype reduced the shrapnel distance to 30 meters to limit

the shrapnel hits to only the targeted scenario. Upon detonation SHGR2000 creates 1330 numbers of shrapnel, the pressure wave has limited power in open areas, and the detonation time is 3.5 seconds.

3.3 Data collection

The study presented herein follows survey research where interviews were used as a data collection method. We followed the survey research guidelines by Petersen [13] and considered the common problems and their mitigation strategies in survey research [9] while designing interview questions. The interviewees were asked questions that required one-word answers which would be used for acknowledging their experiences or feelings. Other questions were open-ended to motivate in-depth answers. Each interview was recorded with the interviewee's consent. Overall, seventeen interviewees were interviewed. The participants were required to have some experience in the training of explosives for the data to be reliable.

3.3.1 Interviews

Interviews were conducted in a structured manner individually one on one where each question was read to the participant in the same order. Participants were asked in person a set of twelve questions that required different types of answers. The questions are presented below.

- Yes-no questions:
  - Do you think that VR can be an effective tool for educational purposes for explosives?
  - Was NadEm fun / interesting?
  - Was NadEm enough for you to understand the interview questions?
- Questions expecting answers on a scale of 1-5:
  - How experienced are you with using explosives
  - How many days per week do you play video games?
  - Do you have experience with virtual reality before you tested NadEm?
- Questions expecting motivational answers:
  - Why do you think that VR technology for explosives is not already used today for the Swedish Armed Forces?
  - What do you think is the positive thing about a VR program for educational purposes for explosions?
  - What do you think is the negative thing about a VR program for educational purposes too explosive?

  - Did you want to have this type of VR program, albeit fully developed, as part of the training of explosives when you went it?

- Other questions:
  - Are you an officer, specialist officer, soldier or civilian employee?
  - How many years of experience do you have with the Swedish Armed Forces?

3.3.2 Sampling strategy

All interviewees, employed by the SAF, are divided into four different job orientations. These different job orientations are presented below with the scope of ranks participated in this study.

- Officer (Lieutenants - Lieutenant Colonels):
  - The officer program is a three year academic education.
- Specialist Officer (Sergeants - Regimental Sergeant Majors):
  - The specialist officer educational program is one and a half years.
- Soldiers (Corporal):
  - A soldier has finished the basic military training.
- Civilian Employee:
  - Civilian employees for the SAF are employed as civilians and they use ranks to show their competence. Civilians employees use military ranks but with a purple mark.

Interviewee	Job orientation	Experience[a]	Knowledge[b]	Organisation
Interviewee 1	Officer	34	5	SWEDEC
Interviewee 2	Civilian employee	-[c]	5	SWEDEC
Interviewee 3	Officer	40	3	SWEDEC
Interviewee 4	Civilian employee	9	5	SWEDEC
Interviewee 5	Officer	-[c]	5	SWEDEC
Interviewee 6	Specialist Officer	12	4	SWEDEC
Interviewee 7	Specialist Officer	-[c]	5	SWEDEC
Interviewee 8	Specialist Officer	-[c]	3	SWEDEC
Interviewee 9	Officer	35	5	ING2
Interviewee 10	Civilian employee	-[c]	5	SWEDEC
Interviewee 11	Officer	22	5	SWEDEC
Interviewee 12	Officer	25	5	SWEDEC
Interviewee 13	Specialist Officer	8	2	MarinB
Interviewee 14	Soldier	7	3	F17
Interviewee 15	Specialist Officer	10	5	MarinB
Interviewee 16	Officer	10	3	MarinB
Interviewee 17	Specialist Officer	10	2	MarinB

[a]Years working in/for the Swedish Armed Forces.
[b]Self-estimated value of their knowledge for explosives on a scale of 1-5.
[c]Interviewee would not disclose.

Table 3.1: Interviewees information

3.3.2.1 Organisations

Organisation		Service branch	Participants
SWEDEC	Swedish EOD and Demining Centre	Army	11
ING2	Göta Engineer Regiment	Army	1
MarinB	The Naval Base	Navy	4
F17	Blekinge Wing	Air force	1
Total			17

Table 3.2: Participant per organisation

As shown in table 3.2, the participants came from four different military organisations. These four organisations cover three service branches of the SAF. The participants from MarinB are officers and specialist officers who train soldiers in all aspects of their military training. The participant from F17 is a soldier and has been educated in explosives. The participant from ING2 is in charge of simulations for that organisation and has expert knowledge in explosives and simulations.

According to the SAF website [2] SWEDEC "is Sweden's centre of excellence for national, military, police, and international missions within the area of Explosive

Ordnance Disposal (EOD). SWEDEC works in both military and humanitarian operations, with focus on training, development and operational support". SWEDEC has the highest level of experience and competence in explosives within the SAF. Working with SWEDEC has been crucial for acquiring the most reliable and qualitative data to analyze. Most interviewees who participated from SWEDEC were of the higher to the highest ranking officer in their job orientation.

3.4 Data analysis

Thematic analysis is used for analyzing qualitative data collected from the interviews. This method of analysis works because the gathered data is qualitative and not quantitative [6]. Cruzes and Dybå [6] present a five-step strategy where each step is thoroughly explained which makes it easy to follow. Cruzes and Dybå's [6] research is aimed to use thematic analysis on data from an empirical software engineering approach. Braun and Clark [5] have a similar thematic analysis approach which has six steps aimed at psychology.

A mix of these two approaches was used to analyze the data collected from the SAF. The result of the two approaches used for thematic analysis is presented in table 3.3.

Phase	Description
1. Extracting data	Transcribing data from the interviews and getting familiar with the data.
2. Identify code data	Identify and extract interesting and relevant concepts from the entire data set.
3. Create themes	The codes data is translated into themes.
4. Mapping themes	Creating the overall story of the analysis. The story is created by combining themes with relations. The themes that are mapped together creates a Higher-Order theme.
5. Producing Report	Providing evidence for the themes and story to assess trustworthiness. Extract examples and relate the analysis to the research questions.

Table 3.3: Phases of the thematic analysis

Chapter 4

Results and Analysis

The structure of this chapter is divided into three sections. The section 4.1 presents the thematic map where each component and its structure are presented and analyzed. In section 4.2 the research questions are answered and linked directly to the analyzed thematic map from section one where evidence has been provided for each theme. Lastly, in section 4.3, the trustworthiness of this research has been analyzed for the reader to get a more transparent picture when reading the results and analysis.

4.1 Thematic map

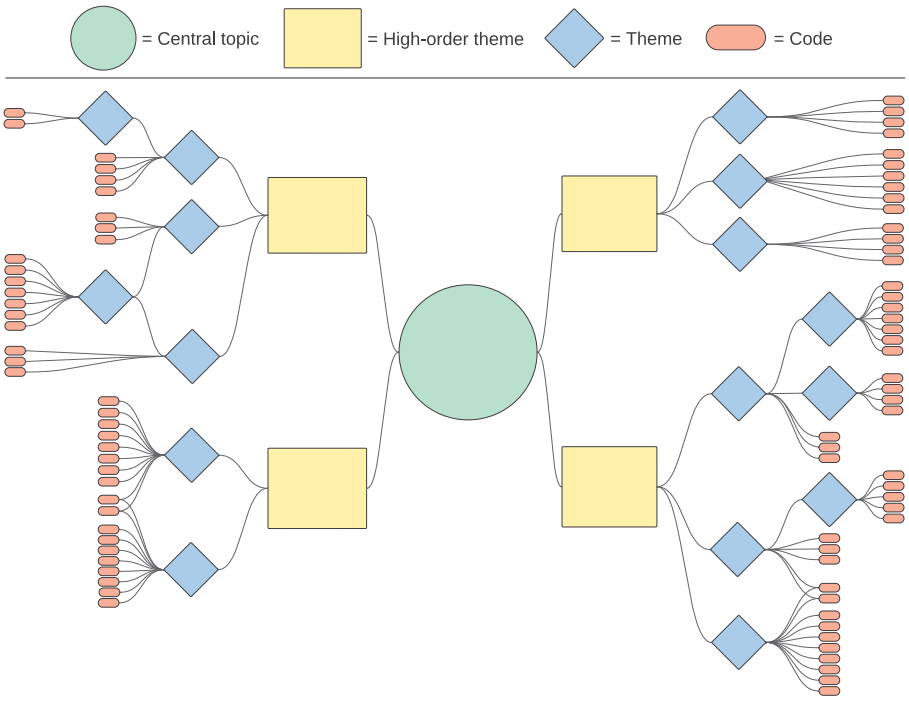

Figure 4.1: Final structure for thematic map

The resulting thematic map structure and what each component represents is presented in the figure 4.1.

4.1.1 Perceived obstacles to the adoption of VR

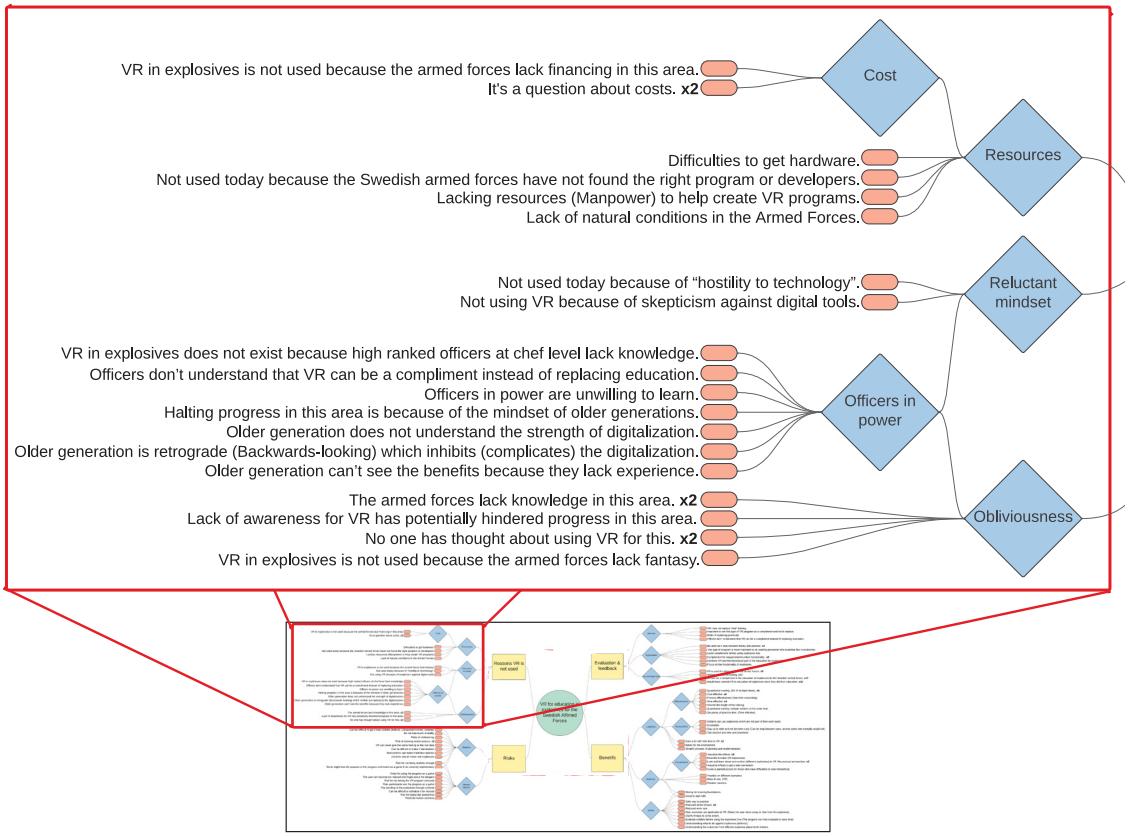

Figure 4.2: Codes and themes in the high-order theme 'Perceived obstacles to the adoption of VR'

This High-Order theme is approached from two angles. One of the angles focuses more on the resource aspects and the other angle focuses more on human factors. There were at least three interviewees who argued that VR not being used in the education is a question of costs, to buy or create a program with good enough quality. The costs could be linked to the lack of financing which is something a couple of interviewees mentioned.

> *"It could be a budget issue or if it is not even intended, I do not know."*
> - Interviewee 13

> *"I actually do not know. Lack of imagination and funding I say"*
> - Interviewee 14

> *"I think it's about money..."* - Interviewee 6

Whether the cost or lack of funding has any impact on this issue is difficult to argue, because the gathered data shows that there are only a few interviewees who mentioned it. The interviewees were honest by saying "I do not know", "I think..."

and "I actually do not know..." shows that these answers are more guesses than based on experience and knowledge. It is not possible, with the information they gave us, to demonstrate that cost or lack of funding is a contributing factor to VR not being used in this area. The theme called 'Resources' is directly impacted by the cost and lack of funding question because the hardware is bought and manpower is paid with salaries. Because of the direct correlation, no further focus is put on this area.

According to the data collected, the main reason for VR not being used today in the SAF in the education of explosives is human factors. These factors have been separated into these three different themes.

4.1.1.1 Reluctant mindset

This mindset inhibits the development of digital tools. Words like 'hostile' and 'skeptical' where used to describe the mindset of individuals when introducing VR.

> *"I think in general we have been very skeptical about using digital aids at all. We have training programs, etc. but when it comes to explosives, we would like to have complete control over this and it has probably hampered us."* - Interviewee 5

> *"There is always a risk that it may start to replace some of the practical exercise that is also needed.."* - Interviewee 8

> *"I think that you still have to throw real hand grenades to get a feeling, it's absolutely important. Because here* (VR) *you do not feel anything even if you get to see it, it makes a difference to feel the pressure wave."* - Interviewee 14

As per the opinion of an interviewee, there is a relation between skepticism of implementing a digital tool to the fear of not being in full control officers are used to when educating soldiers. From the High-order theme 'Evaluation and feedback' there is a theme called 'Worries' which strengthens that there is a fear of losing control if parts of the education get replaced with a digital tool. More than one interviewee, express that some practicals are not replaceable and should not be replaced. Before the interviewee was asked any questions, they were told clearly that a fully developed program similar to NadEm would not replace any practical steps. With this knowledge participants still expressed a worry which shows that there might be difficult to overcome the fear which might increase skepticism and inhibits the implementation of VR for explosives. Each interviewee were told exactly this quote:

> *"The idea is that the VR program should be a complement to the training of explosives and not replace the practical, ie to actually throw a grenade. From theory, to VR, to the practicals"* - Anthony Colton and Sebastian Säbom

The majority of participants from SWEDEC seemed to initially be showing skepticism towards using VR as a tool for explosives. However, their mindset seemed to changed when they used NadEm, they became more positive, curious, and interested in the program.

4.1.1.2 Obliviousness

This theme compared to 'Reluctant mindset' focuses on the area of knowledge and awareness instead of the mindsets of individuals. Not everyone can be against or skeptical to digitize education for explosives so what are other reasons? According to the data collected, there seems to be a lack of knowledge and awareness of modern technologies which might make it difficult to acknowledge the possibilities for VR. Interviewees who were technologically inclined would express the frustration of individuals who have less or no understanding of technology.

> *"I think it has to do with the fact that one is not sufficiently aware of what is there, so to speak. I think there is a conservative vein* (mindset)*. As far as I know, I have never seen any simulators in this way in VR."*
> - Interviewee 8

> *"I think there is a lot of ignorance and that the they* (SAF) *do not want either."*
> - Interviewee 17

To be oblivious to the use of VR in explosives seems to go hand in hand with the theme 'reluctant mindset' according to more than one interviewee. They express that obliviousness might be directly caused by a conservative mindset of wanting something they can control and easily understand and therefore actively avoid listening and learning about modern digitized tools.

4.1.1.3 Officers in power

This is a sub-theme derived from both 'Reluctant mindset' and 'Obliviousness'. It was created because a pattern was found in the code data where most of the information from the parent themes were direct blaming older generations within the SAF for why VR is not used today for explosives.

> *"I think it's a generational issue that older officers may not have used that technology themselves and do not see the benefits of it."*
> - Interviewee 2

> *"I think that because the technology is new and that there are too few high up* (Rank) *who have experience of it so I think it is a generational issue"*
> - Interviewee 7

> *"Officers at the chief level, the Swedish Defense Materiel Administration, the headquarters and the army staff have no idea what this* (VR) *is. I work a lot with just trying to talk about this. I think it is the managers who set up and decide the directions, unfortunately they have no idea what this* (VR) *can do. The general perception is unfortunately that it is better to shoot live ammunition because they do not understand that it* (VR) *is a complement."*
> - Interviewee 9

As per the opinion of an interviewee, VR is a new technology, and to get a quality VR experience has only been possible, arguably since 2017 when companies such as HTC, Google, Apple, Amazon, Microsoft Sony, Samsung, etc started to develop their own VR headsets. Because this technology is young, it might be easier for the younger generations to understand and learn how to use and implement it. The older generation would have to learn from the younger generation about VR. In the military, it often means that the older generation has higher ranks and a dilemma occurs where a power dynamic might feel questioned when a lower rank officer would need to teach the higher ranked ones.

> *"And then there are certainly those who drive development, ie the development managers themselves. We* (Older generation) *are not at the same level as you younger guys, so we're probably a little reluctant. One could even say backward-looking."*
> - Interviewee 5

Some interviewees who see themselves to be of the older generation would blame themselves for being reluctant and backward-looking. This shows that there is an overlap of understanding between generations on this issue.

> *"... Too few people listen to the person I just texted (simulation officer) for example. That, interpret me correctly, but the previous interviewee* (Older generation) *who was interviewed, there are a little too many of them who are managers who do not have an understanding of what power and for what you can use it* (VR) *for."*
> - Interviewee 6

One interviewee would blame the officer who was interviewed before him even though he had no idea what that officer said during the interview. This means that there might be a mindset of the younger officers like him that all officers are backward-looking and reluctant to new technology. In fact, the older officer before him was positive and saw much potential in implementing VR for explosives. This could mean a few things, either that the young officer made an assumption about the older officer, or that the older officer learned and changed his mindset during his use of NadEm. This could mean that the younger generation is approaching the older generation the wrong way when introducing new technology. The approach of letting individuals with less experience try a prototype as a strong way of changing mindsets is strengthened by one interviewee who is of the older generation, he says:

> *"I think it's very good to do a short demo* (NadEm) *to start a mindset or to bring up a thought rather than just asking questions. I was standing in my office just now, so I think that's good."*
> - Interviewee 7

4.1.2 Benefits

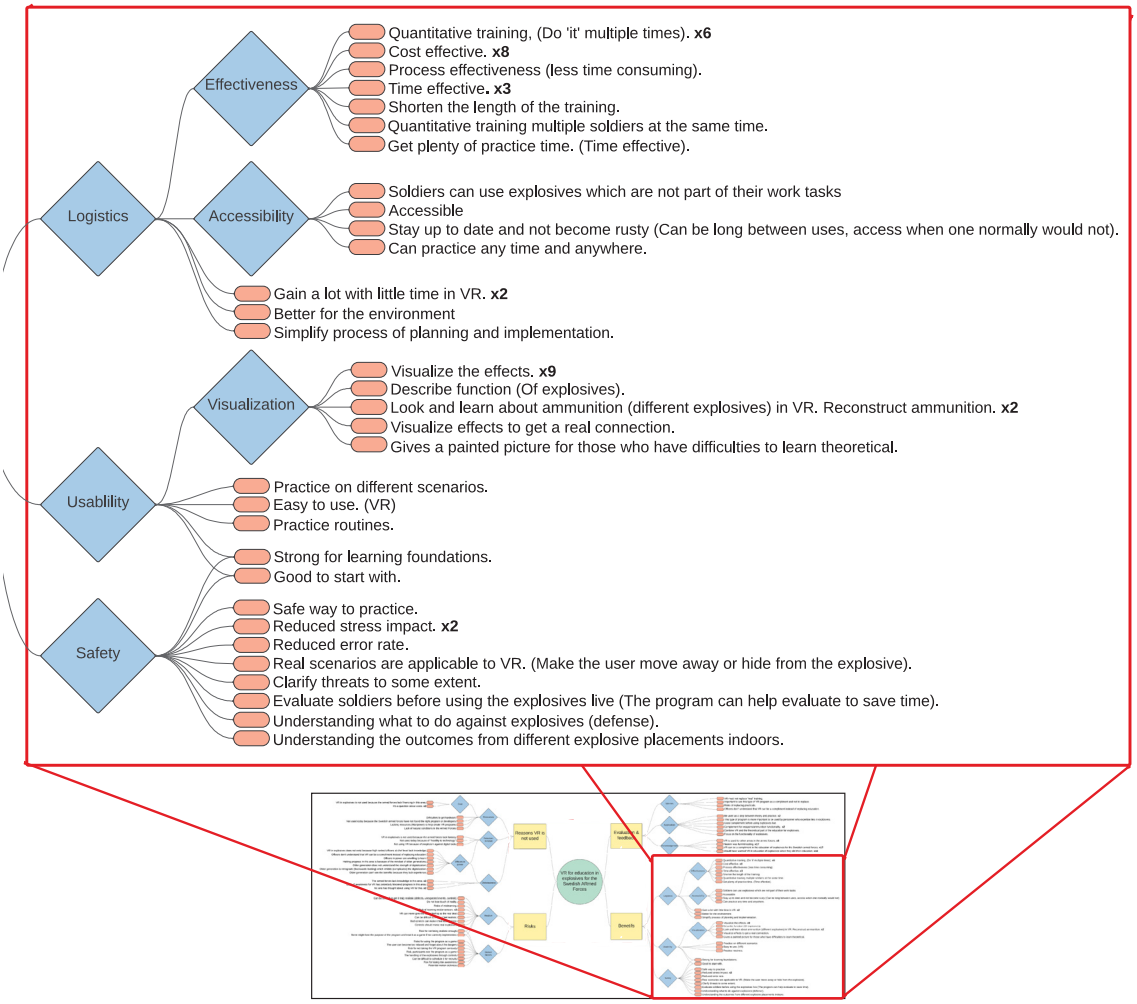

Figure 4.3: Codes and themes in the high-order theme 'Benefits'

The potential benefits of using VR in the education of explosives have been divided into three main themes which cover different aspects interviewees see as potential benefits.

4.1.2.1 Logistics

This theme contains two sub-themes called 'Effectiveness' and 'Accessibility'. The benefits gathered here are all connected to how the logistics could be improved by implementing VR for explosives. To work with live explosives, requires thorough planning, and time to make sure that the education is safe. Because of this process, there is a lack of quantitative training for soldiers which might reduce quality and an individual might not get the experience they should have before going into real combat. One interviewee summarizes it like this:

> *"To go out on the training ground for hand grenades, with his 30 soldiers, each throwing a grenade. I should not say that it is an expensive exercise because there are significantly more expensive activities, starting a JAS (SAAB JAS 39 gripen a Swedish fighter jet) engine is not cheap, but it costs time, it costs bookings, it costs ammunition to be bought, picked up at the warehouse. It is food that is to be driven out, so somehow there is a price tag on that exercise and it takes a whole day and when we are done, everyone has basically stood against a wall and done this (Gesturing a grenade throw) one time."*
> - Interviewee 7

According to one interviewee, the cost of using live explosives like a hand grenade is not an issue but the cost of time and logistics is. This time could arguably be spent more effectively by learning the basics in VR where more time is spent on actual training with the explosives instead of spending it on logistics. A soldier or an officer could even spend their free time honing their skills, which would be difficult or even illegal with live explosives.

> *"The advantage of this* (NadEm) *is you can do it at anytime, there is nothing that really affects only the equipment is there and there is room for it."*
> - Interviewee 17

> *"since my job does not involve hand grenades and such that much, I have thrown very few. Having then had the opportunity to use this* (NadEm) *much more would probably have made one better at it"*
> - Interviewee 17

Interviewees who work for other organisations than SWEDEC expressed that they don't use explosives as part of their work task and thus could benefit from a VR program to keep their skills fresh during the long periods where they don't use explosives. Individuals from one organisation could also try and get an understanding of explosives that are used by other organisations. This could create a better knowledge between organisations and heighten the effectiveness during joint operations. An example would be that soldiers who call artillery could now use VR to understand the effects of the ammunition used when prioritizing higher value targets.

4.1.2.2 Usability

This theme contains the data where the benefits of the actual use of a VR program for explosives are discussed. A big part of this theme was how interviewees saw the benefits in the actual visualization that is possible through VR. The majority of interviewees said that visualizing the effects would be beneficial in the education of explosives. Here the user would be able to observe the effects explosives have on different materials. To be able to create their own scenarios a soldier could learn how to maximize their offense and defense against different kinds of explosives. With the possibility of creating their own scenario, the planned operation could be created as a VR environment to practice before execution.

> *"... a bridge is not something you practice on. Now you can suddenly practice blowing up a bridge because you know that a beam is so thick and needs X amount of explosives and then you can actually blow up a bridge...* (NadEm)*."*
> - Interviewee 14

> *"... visualize it at an early stage so you get an understanding of how shrapnel and things fly and why you should lie flat on your stomach. How to throw it* (hand grenade) *especially in an urban environment. Also mix in the walls properties and I think some hours in the training in connection with the theoretical to get it visualized and maybe not practice the methodology itself. But see what happens when you throw grenades in different places"*
> - Interviewee 6

> *"That you can visualize the effects of an explosive grenade. I think that can be good at the beginning of the education. 'This is what it looks like', 'This is the effect' so you know and understand."*
> - Interviewee 9

> *"... it's like in your program* (NadEm) *to look at a roughly like shrapnel image and the part in NadEm connected to the SIB* (combat in buildings) *environment and you possibly see a devastation that could be or you see how the shrapnel image ends up in that house as well."*
> - Interviewee 10

As stated earlier it was presented to each interviewee that a program like this would be a complement to the education of explosives and not replace any practicals. Interviewees would however discuss that some or all theoretical parts could be replaced by this and thus give the theoretical stage a more modern approach. It would create an overlap between the theoretical and the practicals to especially benefit individuals who learn better by visualizing and 'doing' instead of just reading. An example of implementing theoretical parts in VR could be a scenario in the program where an explosive can be taken apart into its individual components and then reassembled.

> *"The positive thing, I think, is that you can directly without having, for example, the ammunition or mine in your hand, you can have it virtually and you can look at it in different ways. Take apart parts, look at spark plugs, explosives and things like that without actually having the gadget but having predetermined it before."*
> - Interviewee 3

> *"It will give a more painted picture because there are many who can not learn as easily theoretically. So I absolutely believe that it is something that is a good thing."*
> - Interviewee 13

4.1.2.3 Safety

To misuse live explosives is dangerous and can be lethal. With the use of VR, this potential danger is completely avoided because no live parts from explosives are present. A soldier can hold the explosive while it detonates to observe the effect from different angles. This creates potential scenarios which are difficult to achieve in real life.

To possibility for soldiers to quantity practice with explosives would give them a strong foundation before they use it live. This could lead to reduced stress when using live explosives. When a soldier practices with explosives in VR and does a mistake, it's important to make sure that there are consequences. The consequence is to ensure that safe usage and correct practices are drilled.

> *"It's a safe way to practice because you can see consequences and when you see consequences in that world (VR), it still becomes like 'Yes, I did wrong'. If you read on a piece of paper, you can not get that feeling, but here you can still get a visual confirmation that it was not good. So you can practice sharp and dangerous moments. It makes sense for learning I think."*
> - Interviewee 2

> *"I believe that you will have a reduced stress effect in use and also a reduced error rate in use. Not on the weapon itself but in how you do it"*
> - Interviewee 12

> *"Clarifications of threats to some extent."*
> - Interviewee 11

> *"Then there are various measures you do before throwing, for example, a hand grenade, which in this case when you are trained in the situation, gets approved by the instructor before, virtually, to then get up and do it sharply. It could be something like 'Yes approved' or 'No you are not approved, go back and train'. 'Approved, follow along' and then we throw it live."*
> - Interviewee 3

As mentioned in the theme 'Logistics', it is possible to quantity train with VR. To quantity train aspects surrounding a certain explosive, the soldier or officer can gather experience which means more knowledge and practicing routines of that explosive. This experience could lead to a greater foundation for understanding explosives.

4.1.3 Risks

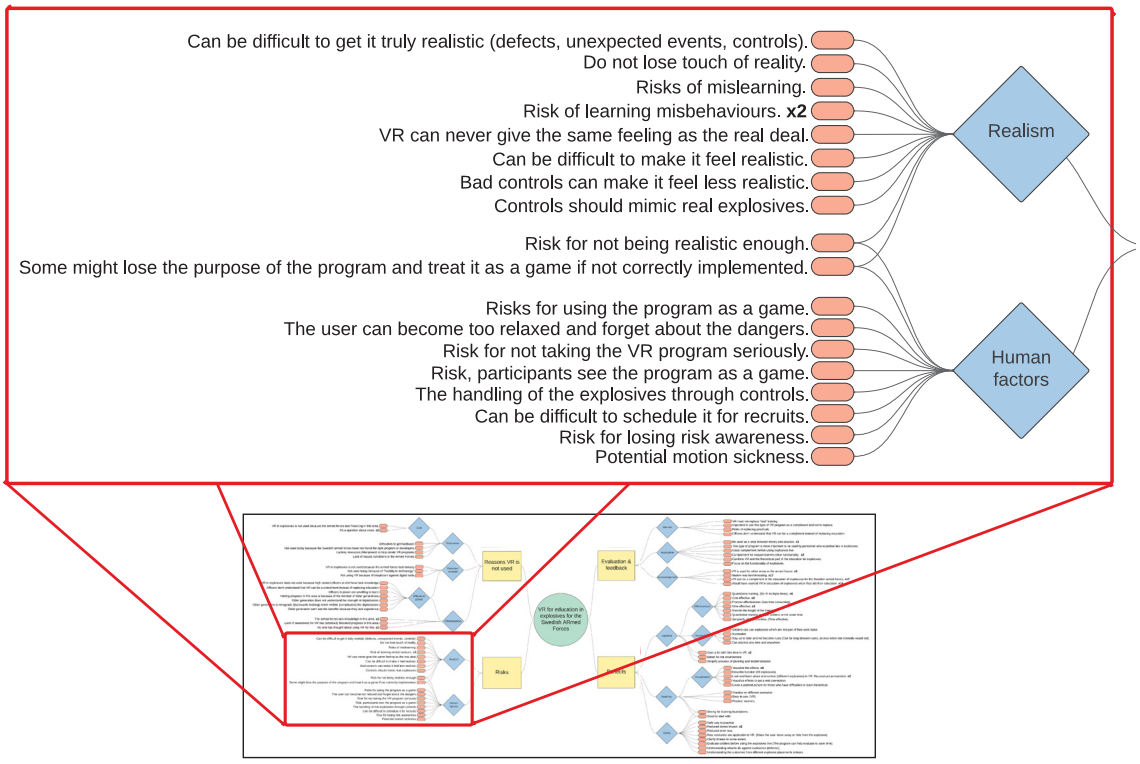

Figure 4.4: Codes and themes in the high-order theme 'Risks'

The risks of implementing VR as part of the education of explosives are divided into two parts.

4.1.4 Realism

To use software to imitate real-life effects might be difficult. Certain aspects are not possible or too difficult to recreate with today's technology, such as recreating the pressure a person feels when a live explosive detonates or the nervousness and anxiety that might imbue a person holding their first hand grenade. Multiple interviewees expressed that this might lead a person to lose touch of reality and show less respect for live explosives.

> *"... one disappears away from the real world, so to speak. In the end, a soldier must run around in reality, shoot with his weapon and throw real hand grenades, then you have to practice that way and such."*
> - Interviewee 4

It has been presented earlier that there are individuals who are concerned that certain steps could be replaced by VR if it was implemented. If steps that are considered crucial by instructors are replaced by VR a risk of losing quality in the education arises. These crucial steps are linked to practicals such as the handling

and usage of live explosives. The risk of using basic VR hand controls to handle explosives was expressed by interviewees to lessen the feeling of realism and their mindset would focus more on how to press the buttons correctly instead of observing and learning.

> *"One downside to this is that I must have pre-determined just for these handles* (Oculus quest 2 handles) *that I got in the fist right now. Here you would want a hand grenade, the same hand grip as in reality if you say so."*
> - Interviewee 3

> *"I must be honest to say that when properly implemented* (VR program) *there are no negative aspects, however, it will be met by 'this can never replace the experience of throwing it* (Hand grenade) *for real'."*
> - Interviewee 7

4.1.4.1 Human factors

The risks linked to human factors might be directly affected by the quality of the VR program. There needs to be a level of realism and seriousness surrounding the program for users not to forget what the program's intended use is. If the program becomes more of a game the user might focus more on having fun instead of learning, which in turn could lead to forgetting the actual dangers which would be present if the scenario was real.

> *"Risk awareness. Because that has been the case with other simulators they have there (Stockholm's amphibious regiment) that it is perceived as a game. The seriousness must remain."*
> - Interviewee 15

An example of this was observed during the interview phase when interviewees used NadEm and only a few of them would 'act out' as if the hand grenade were real. This means that they would call their throws, and count down to detonation while taking cover. This could have been because other individuals felt embarrassed to 'act out' but interviewees from both sides would express their concern that if a user of a similar program never took cover it could manifest when throwing real hand grenades. This is the risk of quantity training wrong behaviors. These interviewees who mentioned this would however say that this is only a risk if the program isn't implemented correctly.

> *"As long as you get software that supports the right things* (Visualization of effects for a hand grenade). *We often use VR for training benefit. If we notice that we have a training benefit from a tool, it is always good. Unfortunately, many push it to the side of the purpose, we do not get the training benefit. It's cool visualization but you lose sight of what's the point of it."*
> - Interviewee 9

4.1.5 Evaluation and feedback

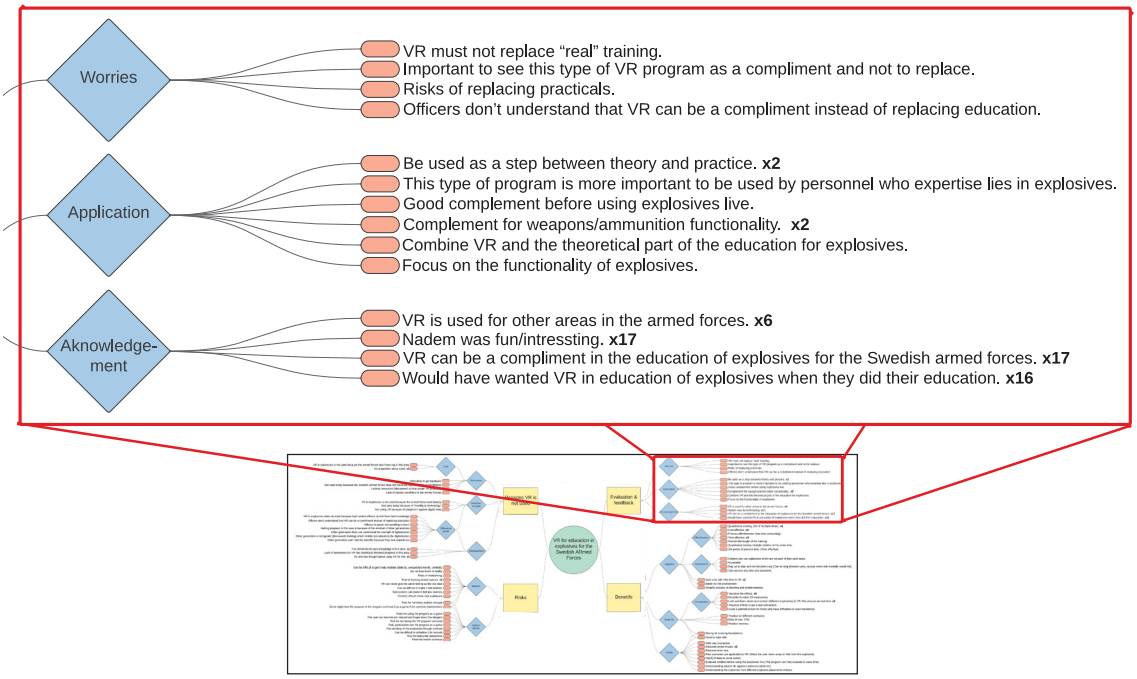

Figure 4.5: Codes and themes in the high-order theme ‘Evaluation and feedback’

All participants find NadEm interesting and fun to use which probably means that this type of tool is not at a high risk of being unused by personnel in the SAF. As well as finding NadEm interesting, all interviewees answered yes if they believe VR could be a complement in the education of explosives. Combining the answers from all questions which are presented in table 4.1 it shows that there exists an overwhelming interest in this type of educational tool for explosives.

The table 4.1 shows that age, rank, and experience have no impact on whether they find a VR tool for explosives fun, interesting and educational.

Interviewee	Interesting/fun[a]	Educational tool[b]	Own education[c]
Interviewee 1	Yes	Yes	Yes
Interviewee 2	Yes	Yes	Yes
Interviewee 3	Yes	Yes	Yes
Interviewee 4	Yes	Yes	Yes (certain areas)
Interviewee 5	Yes	Yes	Yes
Interviewee 6	Yes	Yes	Yes
Interviewee 7	Yes	Yes	Yes
Interviewee 8	Yes	Yes	Yes
Interviewee 9	Yes	Yes	Yes
Interviewee 10	Yes	Yes	Yes
Interviewee 11	Yes	Yes	I don't know
Interviewee 12	Yes	Yes	Yes
Interviewee 13	Yes	Yes	Yes
Interviewee 14	Yes	Yes	Yes
Interviewee 15	Yes	Yes	No
Interviewee 16	Yes	Yes	Yes
Interviewee 17	Yes	Yes	Yes

[a]Thought NadEm was interesting and fun to use
[b]Believes VR can be a complement in the education of explosives for the Swedish armed forces
[c]Would the interviewee like to have had VR as a complement during their education of explosives

Table 4.1: Interviewees yes and no answers

4.2 Answering the research questions

4.2.1 What are the potential benefits of using Virtual Reality as a complement in the education of explosives within the Swedish Armed Forces?

Logistics, usability, and safety are the key areas of potentially benefiting from using VR as a digital tool in the education of explosives. The effectiveness of time, money, and accessibility would improve by complementing the education with VR because the logistics surrounding the training with explosives are extensive to ensure that safety and the right protocols are followed.

VR creates the possibility to practice the steps between theory and practicals. The theory part of the education could be visualized and therefore easier to understand for those who have difficulties understanding the theory just by reading. Since VR does not require any specific logistics, it can be used for quantitative training at any time.

There are no safety concerns when handling explosives in VR which creates opportunities to practice without instructors present. When being able to practice in quantity a soldier or officer gathers experience which could lead to reduced stress and trained routines that could improve the error rate. With the use of VR an instructor would be able to evaluate a student before using live explosives.

4.2.2 What are the potential risks of using Virtual Reality as a complement in the education of explosives within the Swedish Armed Forces?

The risks of implementing VR as a complement for the education of explosives could be mitigated by a VR program with quality assurance. However, some interviewees expressed worries about potential risks regarding misuse of the VR program if the quality is poor. This could lead to learning behaviors that are unrealistic or wrong. These behaviors could lead to dangerous situations if a person is not following the correct safety steps when using live explosives.

VR must be implemented into the education for explosives correctly to not risk mandatory educational areas being negatively affected. These practical areas are, according to most interviewees, personnel needs to be able to feel the pressure of the detonation and practice with real explosives before using them in combat.

4.2.3 What are the perceived obstacles to the adoption of VR for explosives education within the SAF?

Individuals who know why VR for explosives could be a good complement in the education of explosives find it difficult to persuade individuals who lack this knowledge. Usually, these two groups are of different generations which also means different ranks and thus different power to decide on new implementations. According to both generations, the officers in power are reluctant to change their mindset to be willing to learn enough to implement this technology for explosives.

4.3 Questioning the trustworthiness of the research

Interviewee	Gaming experience (1-5)	VR experience (1-5)
Interviewee 1	1	1
Interviewee 2	1	2
Interviewee 3	1	1
Interviewee 4	5	2
Interviewee 5	3	1
Interviewee 6	1	2
Interviewee 7	2	1
Interviewee 8	1	2
Interviewee 9	2	5
Interviewee 10	2	2
Interviewee 11	1	1
Interviewee 12	1	1
Interviewee 13	1	2
Interviewee 14	5	2
Interviewee 15	1	1
Interviewee 16	3	1
Interviewee 17	4	1

Table 4.2: Interviewees gaming and VR experience

In table 4.2 the result of each interviewee's self-estimation on how much they play video games and VR is presented. Knowing how much the interviewees play video games and VR could give the reader a deeper understanding of the answers provided by the interviewees and thus gain context to be critical. Interviewees with more experience with these types of applications have an easier time being creative in their thought processes when looking for the possibilities VR can offer compared to those who lack these experiences. The experienced interviewees were more confident in their answers and reasoning probably because they can relate more to the discussed subject. If the combined experience would have been higher among all interviewees, it's possible that the answers would be broadened and deeper which means that the results in this research might be narrow and lack potential benefits and risks.

Chapter 5

Discussion

The key findings from this study are based on expert opinions. Their opinions and thoughts were surprisingly similar even though their background, rank, and age can be considered vastly different. Because of this, the research questions could be answered clearly.

Our study finds a difference in mentality for implementing modern digital tools into the military because of the officers in power or the 'older generation' not understanding its potential. Officers with a reluctant mindset seemed more willing to listen and learn about implementing VR after using such a tool. The different mindsets might negatively affect other areas in the SAF and not just when implementing VR. By interviewing military personnel from different generations, the understanding of this issue is mutual, and thus it is not impossible to modernize the mindset of personnel mostly from older generations. As shown in this study, it helped to expose them to the VR program NadEm and change their mindset by giving them experience in a fun and exciting way. An unexpected result was that every interviewee found NadEm fun and interesting regardless of their experience, especially within gaming and VR. The benefit of NadEm is that the interviewees could fully immerse themselves into the virtual environment to get better at understanding principles and understanding concepts easily, as found by Akman & Çakır [4] and Xie et al. [16].

There seem to be multiple potential benefits of implementing VR to complement the education of explosives for the SAF. The most beneficial areas that could improve with the implementation of VR are cost, safety, and logistics. The improvements related to costs are widely shared between interviewees, but it is speculative because no proof is presented for why that would be the case. More studies need to be done to get concrete figures on the possible costs of implementing and using VR. The result of the safety aspect of implementing VR in this area concurs with the studies of Li et al. [11], and Zhao and Lucas [17] that VR is a safe place to practice dangerous scenarios and identify potential risks before doing the task live.

The risks of implementing VR in the education of explosives could probably be mitigated if developed correctly. The likeability of the simulation is important for the students to be engaged, interested, and motivated to learn, as shown in studies by Virvou and Katsionis [15] [14]. The same applies to this study; however, there needs to be a middle ground between fun and seriousness for military personnel, so the safety aspects of their education are not affected negatively.

Chapter 6

Conclusions and Future Work

Our study shows that there is a shared interest in implementing modern digitized tools such as VR into the education of explosives and that there are many potential benefits that outweigh the potential risks. The risks can be mitigated by the quality of the program, which in turn means that the quality of the education depends on how well VR is implemented. It is perceived that A VR program like this is not implemented today because of the older generation who lacks knowledge in this area and thus inhibiting the progress. The findings of this study may be applied to other sectors such as healthcare, infrastructure, and other sectors where risk awareness is highly prioritized.

The costs of using VR are improved according to the interviewed military personnel. The actual difference in cost when having VR complementing certain areas of education could change the perspectives of the officers in charge of deciding to implement VR or not.

It was mentioned by a few interviewees that VR could be beneficial for the environment because of all the logistics required for using live explosives. This would save vehicle usage, remnants from detonated explosives, and material usage. A further study could find that explosives impact the environment more than expected and, through VR, perhaps lessen the environmental impact.

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Faculty of Computing, Blekinge Institute of Technology, 371 79 Karlskrona, Sweden