Øyvind Jalland Schjerven & Kristoffer Nyvoll

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Master's thesis in Informatics
Supervisor: Sofia Papavlasopoulou
June 2023

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Abstract

The increasing societal reliance on new competencies, often referred to as "21st century skills", impose new and rapidly changing requirements on education. In particular, skills like collaboration, problem-solving, critical thinking and creativity has become progressively more important to acquire. Alas, these skills are seldom acquired through formal education when adhering to traditional, procedural teaching methods. Through application of teaching methods that are inherently more creative, open-ended and generally applicable to real-world situations, the problem-solving in the classroom can better equip learners for success in the modern workforce. This study sought to examine *how students perceive learning in an educational virtual robotics environment with a design thinking approach*. An open-source virtual robotics platform called "Gears" was forked, further developed and used in an empirical study spanning two one-hour sessions with a Norwegian secondary school to address this problem. A design thinking approach was followed in the empirical study. Interviews were conducted, and data was collected through log data, questionnaires and artefacts.

This thesis highlights key advantages of using design thinking in combination with virtual robotics. Chief among the advantages are the broad learning that often exceeds curriculum, and the way design thinking, when used in this context, can aid different students in the specific processes they need most. We also highlight the impact of motivation and attitude, and provide an evaluation of the platform and the study.

Sammendrag

Vårt moderne og teknologiske samfunn er i økende grad avhengig av nye kompetanser, ofte referert til som "ferdigheter for det 21. århundret". Herunder nevnes blant annet egenskaper som samarbeid, problemløsing, kritisk tenking og kreativitet. Samfunnsmessige endringer stiller nye krav til utdanning, som bør etterstrebe å imøtekomme disse endringene for å ruste fremtidige generasjoner for en framtid som er under stadig endring. Dessverre kan det tyde på at formell utdanning som følger tradisjonelle og prosedyremessige læringsmetoder ikke fremmer disse egenskapene i tilstrekkelig grad. Gjennom aktiv bruk av læringsmetoder som per definisjon er mer kreative, åpne og tettere knyttet til realistiske situasjoner, kan utdanning i større grad forberede elever på suksess i det moderne jobbmarkedet. Denne masteroppgaven undersøker *hvordan elever oppfatter læring i et virtuelt robotikk-miljø som følger en design thinking-tilnærming.* En plattform ble utviklet og brukt i en empirisk studie som strakk seg over to enkelttimer på Vestsiden Ungdomsskole i Kongsberg. Åpen kildekode ble klonet og videreutviklet for å produsere en plattform som kunne besvare forskningsspørsmålet, og studien benyttet en design thinking-tilnærming. Datainnsamling ble gjort gjennom datalogging, spørreundersøkelser, artefakter, samt intervjuer.

Denne oppgaven fremhever fordeler med design thinking i kombinasjon med virtuell robotikk. Blant disse er de mest fremtredende det brede læringsutbyttet, som ofte dekker mer enn planlagt pensum, og hvordan design thinking brukt i denne konteksten kan hjelpe elever i de spesifikke prosessene de trenger det mest. Vi fremhever også betydningen av motivasjon og innstilling, og gir en vurdering av plattformen og studiet som er gjennomført.

Acknowledgement

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1 Introduction

Success in the highly competitive modern world increasingly depends on new competencies and skills, many of which are acquired through educational institutions [1]. The skills required for success have evolved with time, and some traditional education methods show insufficiency in equipping students with the necessary skills for the future, which largely pertain to communication, collaboration, complex problem-solving, critical thinking, and creativity [2]. In response to this challenge, new approaches and technologies have emerged to potentially provide more effective approaches to education. Design thinking and educational robotics are two examples of this, as both have gained traction in education and have shown promise in promoting the competencies required for success in the modern world [3].

Design thinking is a problem-solving approach that has been widely used in creative industries, such as product design and web design. Recently, design thinking has also become more widespread in education, given its relevance and carryover to the emerging competencies required in the modern world. Educational robotics, on the other hand, involves using robots in educational settings to teach students about science, technology, engineering, and math (STEM) concepts. Both design thinking and educational robotics have been shown to promote the aforementioned competencies, which are collectively referred to as 21st century skills. A search for an interesting subset of educational robotics referred to as ”virtual robotics” only yields a tenth of the results on Google Scholar compared to ”educational robotics”, implying that it is less researched in comparison. Virtual robotics purely consists of software and is therefore devoid of physical robots.

Providing proper education to children and young adults is one of the most determining factors of a successful career, as it teaches them how to learn and thereby acquire the aforementioned competencies [4]. The learning process is complex and widely researched. Still, the development of new technologies have revolutionized education numerous times in the past, which makes a compelling argument for continuous research in education. In other words, the fact that emerging technology could produce new and synergistic ways of optimizing education, combined with the obvious importance of education, motivates further research.

The increasing societal reliance on technology mandates a greater emphasis on the integration of technology in education, and the growing inclination among educational institutions to incorporate technology into K-12 education, therein kindergarten to 12th grade students, is likely to continue [5, 6]. This trend has been fueled by the recognition that technology can play a crucial role in preparing students for the demands of the 21st-century job market. Specifically, there has been a surge in the integration of STEM education, digital literacy, and computational thinking in K-12 curricula [7]. Moreover, educational institutions are increasingly leveraging educational technology tools and platforms to make learning more engaging and interactive for students [6]. Overall, the growing adoption of technology in K-12 education reflects a significant shift in the way educational institutions approach teaching and learning [8]. Based on this, we postulate that this trend is likely to continue in the future as schools strive to equip students with the skills they need to succeed in the modern world.

This study seeks to explore the potential of design thinking in virtual robotics environments to promote 21st century skills in K-12 education. The study is timely, given the potential of new approaches to learning and problem-solving in virtual education environments combined with increasing societal openness to digitization. The findings of this study contributes to the body of knowledge on the use of design thinking in education, and provide insights into the challenges and opportunities of using virtual robotics environments in education.

1.1 Problem Description

Despite the potential benefits of combining design thinking and robotics in education, research on their synergistic use is still lacking. On their own, both have received attention from the research community, and deservedly so. Indeed, educational robotics has been researched and adopted in an increasing number of educational settings, and the systematic literature review conducted by Benitti showed promising results for the use of robotics, particularly to aid the understanding of concepts related to the STEM areas [9]. Xia and Zhang confirm Benitti‘s findings, as their systematic review indicated optimistic learning outcomes of students, including the improvements of knowledge, attitudes and skills [10]. However, the subset of educational robotics that we refer to as ”virtual robotics” has received little attention relative to educational robotics, although the number of papers on the subject is increasing. Virtual robotics is devoid of the costly and high-maintenance physical robots and has been shown to elicit greater learning dividend than physical robotics in some cases, which makes it an interesting topic for further research [11].

The K-12 educational system is challenged with new demands to meet the rapidly changing societal needs of the 21st century. Many parts of the current system relies on traditional teaching methods that prioritize procedural learning, leading to a lack of critical thinking, creativity, and innovation. This procedural approach can inhibit genuine creative work and has less applicability to the real world, implying that education instead should strive to inculcate an attitude of enquiry in their students [12]. Moreover, there is a growing need for digital literacy and other 21st century skills, which the traditional system is ill-equipped to provide unless it evolves with society. To address these issues, further development of educational approaches is needed, with a focus on critical thinking, digital literacy, and the development of 21st century skills. This requires further research and experimentation with new teaching approaches.

Many existing papers have examined how students think whilst solving educational-robotics-tasks. Incidentally, these papers relate to computational thinking, and not design thinking. Similarly to design thinking, computational thinking is an approach to problem-solving, but it involves breaking down complex problems into smaller parts and using computing concepts like algorithms and pattern recognition to create solutions. Despite the obvious usefulness of computational thinking, not all problems are best solved with computing concepts. Since design thinking is domain-agnostic, it is more applicable to everyday problems. Expanding on the current body of research with a more generalizable problem-solving methodology like design thinking could therefore be valuable.

1.2 Research Question

Based on the above problem description, we propose the following research question:
How do students perceive learning in an educational virtual robotics environment with a design thinking approach? By answering this research question, we extend the current research and shine light on a potentially synergistic combination that seems promising for fostering ”21st century skills”.

1.3 Research Approach

The steps preceding the writing of this thesis was planned and divided into six steps, as listed in Table 1.

Table 1: The approach followed for this thesis.

Step	Explanation
SLR	A systematic literature review (SLR) was conducted on the combination of ”design thinking”, ”educational robotics” and ”virtual robotics” in order to gauge the current body of research, gain familiarity with the appropriate topics and identify a worthwhile research gap. 35 papers resulted from this step, which is elaborated on in Section 2.3.
Technology research	In total, over ten open-source alternatives were tested and reviewed in order to identify appropriate software libraries and tools that would enable plausible completion of the development in time for user testing. An open-source project called ”Gears” emerged as the unequivocally superior choice.
Research design	The planning of the research design was influenced by the SLR, and interrelated with the technology design, resulting in a mixed-method research design with triangulation.
Development	The platform was forked from ”Gears” and further modified to meet criteria after completion of the above planning steps.
User testing	The empirical study was carried out on a Norwegian secondary school using the developed platform.
Data analysis	The data collected through user testing was analyzed and included in the thesis.

1.4 Research Method

For the empirical study of this thesis, we implemented a mixed-methods design and methodological triangulation to answer the research question. Interviews were conducted, and data was collected through log data, questionnaires and artefacts to investigate how design thinking can be used to aid problem-solving, as well as stimulate performance and excitement in a virtual robotics environment.

1.5 Thesis Structure

Section 2 explains the background for this thesis, based on the SLR that was conducted in the preceding prestudy. Section 3 describes the software implementation of the platform, based on a set of objectives. Details about how the user testing for this platform was performed is included in section 4. The results of this user testing are presented in section 5, which are then discussed in section 6. Finally, we conclude the thesis in section 7.

2 Background

The authors of this thesis conducted a systematic literature review in 2022 to examine related research on the intersection between the topics of educational robotics, virtual robotics, design thinking, and how these relate to learning and education [13]. In this section, we start by defining the relevant terms, before describing how the systematic literature review was performed. Sections 2.3.1, 2.3.2 and 2.3.3 establish the current body of research on the aforementioned topics. The related work in these sections follow from the SLR. The related work is therefore similar to the SLR conducted in 2022, which was written as a preparatory project to collect sufficient data to the topics in this thesis. Lastly, we elucidate gaps that the current body of research is yet to answer and present the goal of this thesis.

2.1 Definitions

Some of the terms frequently used in this thesis can have multiple definitions, and are often used ambiguously and interchangeably with other similar terms in the literature. For the sake of precision, we succinctly define them as they relate to this thesis.

21st century skills

The related work on the field pertaining to education and learning, especially within the scope of educational robotics and other STEM-related subjects, frequently mention the term "21st century skills". As stated by McComas, there is not a single set of 21st century skills, but many lists refer to skills for the workforce, personal, interpersonal and life in general [14]. Shute & Becker instead ask *what domains in our twenty-first century world are worth learning* [1]. While supporting the idea that there does not exist one agreed upon and general list of 21st century skills, some relevant key skills should be highlighted within the domain of the STEM-related personal and workforce skills, which is cultivated from the papers of the systematic review. These skills include a range of abilities that are important for success in today's rapidly changing and technological world. These skills include critical thinking, problem-solving, creativity, innovation, communication, collaboration, and digital literacy.

Problem solving

The frequent mentions of problem-solving call for a definition that counteracts the inherent ambiguity of such a broad term. We refer to the definition used by Cinar et al. for problem-solving as it relates to education: "*Problem-solving comprises a series of mental, emotional, and behavioural efforts that an individual exhibits in order to find an effective way to cope with the problematic and stressful situations confronted in professional and everyday life. The development of students' problem-solving competences is one of the most desired educational outcomes for life. However, real-life problems are rather dynamic, complex, and versatile compared the ones predefined in structured formal learning contexts*" [15].

Constructionism

Constructionism is an educational philosophy that emphasizes the importance of students constructing their own knowledge through hands-on, experiential learning. According to this philosophy, students are more likely to retain and understand new information when they are actively involved in the process of creating something, rather than simply receiving information. Constructionism can be used in education by providing students with opportunities to engage in activities that allow them to construct their own understanding of a subject, such as creating a robot or conducting an experiment. This approach can be particularly effective for STEM-subjects, where hands-on learning can help students better understand complex concepts and theories. This term is frequently mentioned in the related research, and will hereinafter be used to denote the general philosophy of education that emphasizes "learning by doing". Albeit not directly related to the findings of this thesis, the thematic similarity with design thinking and educational robotics calls for the inclusion of constructionism.

Design thinking

Similar to constructionism, design thinking is complex and difficult to define without oversimplification [16]. In a nutshell, design thinking is a problem-solving approach that enables iteratively generating, testing and refining ideas. Design thinking involves understanding the user's perspective, empathizing with their problems and needs, thereby producing solutions that are both effective and desirable. The nomenclature varies and the models are many. At their core, most of the models revolve around three main activities: *inspiration, ideation and implementation* [17, 18]. Some of the most commonly used models in education include:

- Stanford Design Council: *Empathize, Define, Ideate, Prototype and Test* [19].
- IDEO: *Discovery, Interpretation, Ideation, Experimentation and Evolution* [18].
- Double Diamond: *Discover, Define, Develop and Deliver* [20].

All of these models share the practice of alternating between diverging and converging on ideas. The former, diverging, focuses on generating ideas and broadening the scope. This is great for brainstorming and creating new ideas. The latter, converging, selects the best ideas from the diverge-step and narrows down the scope. This practice is succinctly illustrated by the "Double Diamond" model in Figure 1. The Double Diamond model was followed in this thesis.

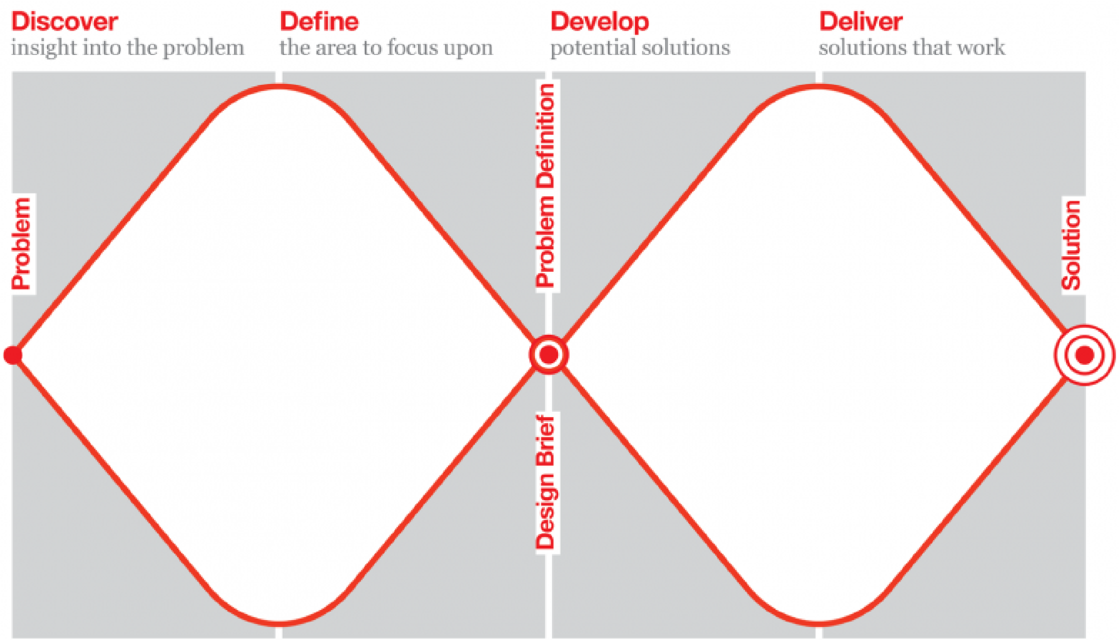


Figure 1: The popular "Double Diamond" model.

Educational robotics

Educational robotics is a teaching method that uses robots to help students learn and develop the aforementioned 21st century skills. This type of education involves students designing, creating, and programming robots to perform specific tasks or solve problems. Educational robotics is usually used in STEM-subjects, often with an additional goal of making learning fun and engaging.

Virtual robotics

The subset of educational robotics that only involves the software component will hereinafter be referred to as "virtual robotics". Virtual robotics refers to the use of software and computer simulations to design, create and test robots. While we solely call it "virtual robotics", we should clarify that we refer to it within the frame of education.

2.2 Systematic Literature Review

A systematic literature review was carried out to form the basis for this thesis. The review was conducted in accordance with the steps described by Xiao et.al [21]. The guidelines regarding data collection, inclusion criteria, screening, and quality criteria and assessment were followed rigorously to ensure high credibility and validity. The primary goal for performing a literature review was to collect papers pertaining to the relevant topics of sufficient size and coverage to provide significant understanding of the current research within the field. As a consequence, we refrained from publishing a standalone paper with the analyzed and synthesised data. In this finalizing step, we deviated from the guidelines that we otherwise adhered strongly to. Instead, the data extraction, analysis and synthesis was performed with the purpose of providing relevant information for sections 2.3.1, 2.3.2 and 2.3.3, which is where the findings of the review are presented. The following three subsections describe how the systematic literature review was performed.

2.2.1 Data Collection

Systematic literature reviews aim to be reliable, accurate and exhaustive. To ensure the attainment of as many relevant papers as possible, a comprehensive data collection is needed. Based on the topics of interest in this review, the following four databases were selected for data collection: Education Resources Information Center (ERIC), Scopus, World of Science and ACM Digital Library. Several searches containing combinations of specific keywords were performed on these databases, and the results were saved and exported for screening. Key search terms used in the queries included "educational AND robotics", "virtual AND robotics", "design AND thinking AND learning", "virtual AND robotics AND learning", "design AND thinking AND robotics" as well as derivatives of these terms. The period examined in the data collection was every year to and including 2022 (November). The data from the following databases were collected in November 2022: ERIC (75 papers), Scopus (352 papers), World of Science (414 papers) and ACM (163 papers).

1004 papers were collected in total, of which 786 distinctive papers remained after removal of duplicates.

2.2.2 Inclusion Criteria and Screening

Following the initial data collection, the papers were evaluated against predefined inclusion criteria, thereby reducing the number of included papers to a manageable amount. Furthermore, it filtered out the papers that inadequately satisfied the necessary criteria, which is an important step for ensuring satisfactory credibility of the literature review. This was done through a screening process, where the key fields of each study were inspected. The type of paper was examined, and books, short papers, posters, unfinished studies and analyses were excluded. Papers pertaining to non-relevant topics were removed, as they were outside the scope of this literature review. This was done by a two step elimination process. First off, the title was considered either "potentially relevant" or "irrelevant". We also excluded studies that were unavailable in English or where the full text could not be found. The abstracts of the unresolved papers were taken into consideration to determine the relevance of each paper. Lastly, we filtered away those who did not pertain to learning or did not involve adolescents or students. Papers from all publishing years were included, as the development of design thinking methodology and educational robotics over time was regarded as valuable information. In addition, no obvious arguments could be made for enforcing a filter on any specific year. Furthermore, we did not differentiate between formal and informal learning, as both could provide insight towards the research question.

168 papers remained after completion of the screening process.

2.2.3 Quality Criteria and Quality Assessment

After screening the papers for the inclusion criteria, the remaining papers were then assessed based on a set of predefined quality criteria. The criteria were defined to ensure the selected papers were (1) *rigorous*; (2) *credible*; and (3) *relevant.*

Criteria:

1. The aims and objectives were clearly reported.
2. There was an adequate description of the context in which the research was carried out.
3. The research design was appropriate to address the aims of the research.
4. Data collection methods were described and appropriate to address the aims of the research.
5. There was an adequate description of the methods used to analyze data, and the data analysis was sufficiently rigorous.
6. The study provided clearly stated findings with credible results and justified conclusions.
7. The study added value for research or practice.

This was accomplished by going through each paper with the appropriate thoroughness, as some papers were easier to assess than others. In this assessment, the introduction, methods and potential findings were given additional attention, as these sections often gave a strong indication to both quality and relevance of each paper.

The completion of this process resulted in a total of 35 papers considered to be of sufficient quality and contextual value. These 35 papers were studied thoroughly, and their contents formed the basis for section 2.3.1, 2.3.2 and 2.3.3.

Numbers for each stage of the selection process is displayed in Figure 2.

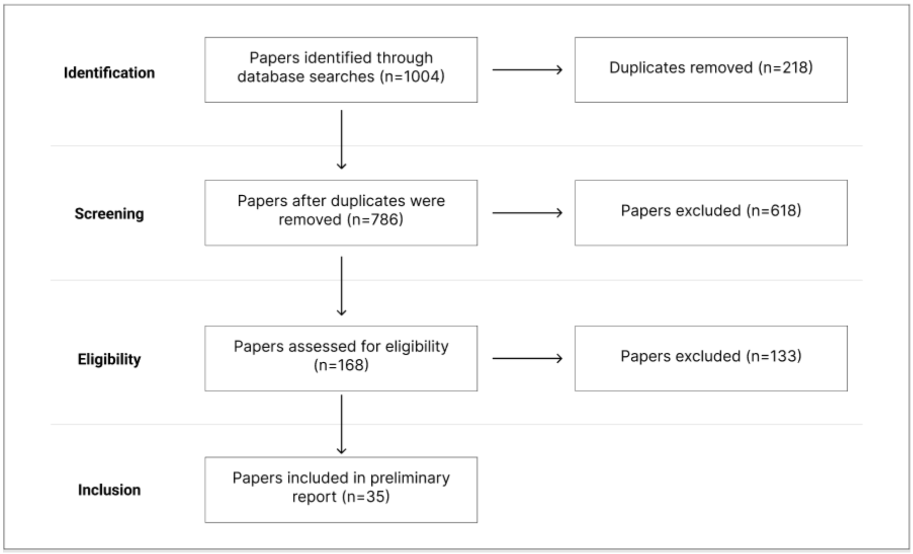


Figure 2: Number of papers included and excluded during the SLR's paper selection process.

2.3 Related Work

The 35 papers that were selected in the SLR formed the basis for this section, and the relevant findings relating to this study are elaborated on in the next three sections. Most of the included related work was derived from the SLR, in which the resulting 35 papers were thoroughly examined and notes pertaining to the efficacy of the relevant topics were taken. Meticulous focus was taken to search for any mentions of the combinations of the topics of this thesis or specific considerations of learning in K-12 education. We highlighted key findings for each paper, and systematically categorized how each paper could be utilized in the writing of this thesis. This required several re-reads to ensure full absorption of the content in the papers.

2.3.1 Design Thinking

Design thinking, as defined in section 2.1, is a human-centered approach to problem-solving that enables iteratively generating, testing and refining ideas. In this way, design thinking helps generate creative and effective solutions to complex problems by encouraging collaboration, iteration, and a focus on user needs. Furthermore, it can help decision-makers reduce their cognitive biases by promoting a more open-minded and exploratory approach to problem solving [22].

Design thinking has seen more widespread application within business and education over the last decades. This increase follows the steadily increasing popularity of design thinking, as indicated by the Google Search Trends in Figure 3. Although more research is needed to make general claims about the efficacy of design thinking in education, reviews as recent as 2022 have found that design thinking shows great educational potential in K-12 education [23].

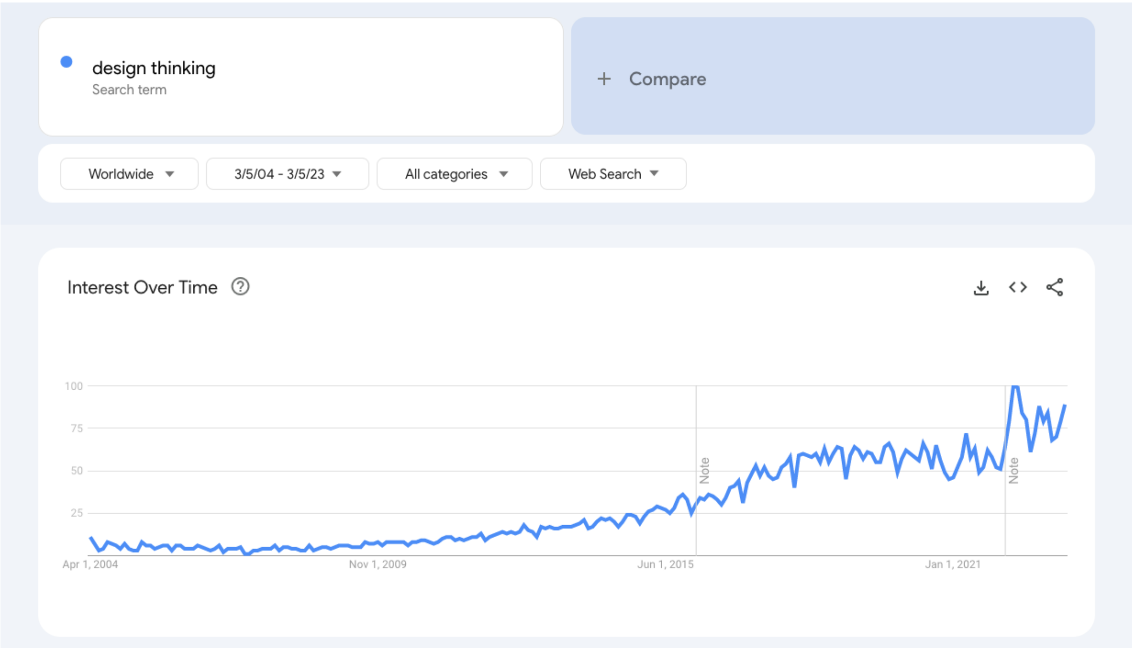


Figure 3: The search frequency of Design Thinking is increasing.

Education that leverages design thinking inherently differs from the procedural nature that currently occupies much of the curriculum used in K-12 education. Procedural approaches are not to be avoided at all costs, but education that follows a procedural approach has several drawbacks. Papers by Bloome et al. and Gibson et al. suggest that a procedural approach to education can lead to a lack of understanding of underlying concepts and skills, and may inadequately prepare students for real-world problems [24, 25]. Learning approaches that implement design thinking ameliorates these problems, as it is better suited for moving students beyond the traditional acquisition of knowledge, and toward the holistic application of acquired knowledge to real life situations

[26]. Helping students think like designers may better prepare them to deal with difficult situations and to solve complex problems in school, in their careers, and in life in general. Current educational practices, though, typically adhere to outdated theories of learning and pedagogy [26].

The process of design thinking is an effective tool for creative problem-solving, as it involves some mindsets or strategies for information collecting, peer discussion, iterating on potential solutions, and understanding the needs of others [27, 28]. Thus, design thinking is an iterative process with a large potential to transform problems into opportunities [29]. The studies looking at how design thinking relates to STEM and computer programming show promising results thus far, but more research on their combined use is required to draw any significant conclusions. Tsai and Wang discovered that the three factors *ideate, prototype and define* significantly predicted the overall computer programming self-efficacy [2]. Loudon found that integrating ideas from design disciplines into STEM curricula can enhance student creativity and engagement [30]. Another study found that the ability to learn physics concepts was significantly enhanced using the design thinking approach, potentially via an increase in motivation [31, 32]. Li et al. argue that design and design thinking are vital to creativity and innovation, and can be developed through design activities in not only engineering and technology, but also other disciplines as well as integrated STEM education [33]. In supporting creative learning, design thinking can represent a generative and positive educational experience, which not only contributes to the knowledge development of individual students but can also result in creative social contributions to students' peers, teachers, and beyond [34, 35]. Overall, the papers suggest that design thinking can be a useful tool for teaching STEM subjects in an engaging and interdisciplinary way.

2.3.2 Educational Robotics

Technology and robotics has been a source of inspiration and curiosity for decades, with stories like Star Wars and Star Trek inspiring us to wonder how the world will look in the future. Technological advancements have brought forth availability to more advanced and sophisticated robots, which have already become an integral part of the lives of many people in the modern world. Many tasks previously performed manually, from simple chores, like vacuum cleaning, to extremely complicated tasks, like air craft navigation, can now be performed by robots. These changes significantly alters the modern workforce, which mandates adaptations in education. Some predictions postulate that 65% of the children entering our schools today may have jobs as adults that do not yet exist [36]. With this increasing presence of robotics in society, there has been a rapid increase in public interest in robotics over the last several years [9]. In fact, the interest of computing in early education has never been as high as now [37]. The public attention robotics are getting can contribute to better understanding of many technical aspects among the populace. Moreover, the attraction to robotics and technology can also be taken advantage of in education by introducing educational robotics. Exposing students to robotics in an educational setting can facilitate increased engagement in complex concepts and cause a spike of interest in STEM-related topics [38, 39]. Robot-based practises can also yield better results when compared to "normal" lectures [40]. Additionally, educational robotics can serve as a fun learning environment for skill development within a wide range of other disciplines, such as social science, literacy and music [41]. This would also allow students to acquire certain skills and thinking patterns that are readily transferable, and thus conducive, to their future learning and problem-solving in STEM-subjects or even everyday reasoning [37]. However, the potential of educational robotics is dependent on how it is implemented. Although robotics can develop personal cognitive, meta-cognitive and social skills, educational robotics on their own is only a tool for learning, and have to be combined with the appropriate educational philosophy and curriculum to optimize learning outcome [42]. Lastly, educational robotics is useful for bridging the gap between classroom learning and the real world by providing students with a tangible, relatable way to apply what they have learned.

The total learning outcome often exceeds the intended learning criteria when educational robotics is involved. Indeed, educational robotics provide great conditions for adherence to constructionism [43]. In most cases, the scenario targets the teaching and learning of one or more main concepts in a curriculum subject area, like programming or robotics. Inherently, the scenarios may indirectly address extracurricular concepts in an interdisciplinary perspective. This is the case when the use of robotics enhances concepts from STEM education in fostering art or social skills [12].

Despite the potential educational robotics has for facilitating complex and open-ended activities, some teachers engage students in procedural (step by step) robotics activities following very tight instructions which prohibits creating an ill-defined situation in which the students can engage their co-creative problem-solving strategies [12]. Design thinking is highly effective at preventing such procedural activities, by engaging the students in an iterative and creative process. This argues for further research examining if one can integrate design thinking in educational robotics, thereby utilizing the positive effects both fields have on the 21st Century Skills.

To summarize the state of educational robotics in 2012, Benitti conducted a literature review to identify the potential contributions of robotics as an educational tool. The results showed that robotics is useful to aid the understanding of concepts related to STEM, but that research pertaining to the correlation between quantitative assessment and learning performance is lacking [9]. Gubenko et al., who later did a study on the creative processes in educational robotics, found that the creative process, in this context, is a multistage dynamic process which builds on existing knowledge and is guided by a productive strategy search. This search is characterized by alternation between generative and explorative thinking [44]. This alternation has uncanny resemblances with the iterative diverging and converging that is common in design thinking. Furthermore, in the same way that design thinking favours ill-defined problems, Gubenko et al. observed that robotics challenges often had multiple viable solution strategies and do not have a single criterion for evaluating the solution. This appears highly synergistic with creative problem solving.

2.3.3 Virtual Robotics

Educational robotics refers to both physical and virtual robotics used in an educational setting. Previously conducted research, especially to measure computational thinking, has mostly been tested with physical robots. This thesis, however, mostly pertains to virtual robotics. Virtual robotics is a subset of educational robotics that only includes the software implementation of robotics, which means that students program, interact with and test their robot in the same program on their computer. Furthermore, virtual robotics adheres strongly to the constructionist philosophy by enabling students complete freedom to familiarize with the curriculum by interacting with the software, devoid of the various restrictions imposed by physical robots.

Virtual robotics tends to be highly customisable and interactive, and have overcome many of the limitations associated with physical robotics. Among others, it eliminates many of the economical issues involved in acquisition and maintenance of the physical robots, while simultaneously increasing the availability of equipment. With virtual robotics, the students solely interact with the software, thereby reducing the scope of possible errors, and increasing precision. Virtual robots are cheaper, more precise than physical robots, and more importantly, they enhance the flexibility of robots and their components as there are no physical limitations. In addition, the behavior and appearance of the virtual robots can easily be manipulated, without worrying about the feasibility of the equipment [45].

Zhong et al. showed that no significant difference was found in the students' learning attitude, programming skills, and learning engagement between a combination of Virtual and Physical Robotics (VPR) and Physical Robotics (PR). Significant differences existed, however, in engineering design ability and cognitive load [45]. Although the VPR strategy was not always better than the PR strategy, it had unique advantages on facilitating students' higher-order thinking in solving complex problems, as well as reducing their cognitive load. The findings of Zhong et al. highlight that VPR is more valuable to the engineering design tasks than PR, and indicate a potential direction in the future to integrate Virtual Reality/Augmented Reality into robotics education.

Virtual robots are commonly regarded as a representation of real-world robots, thus invoking some inherent degree of abstraction. Abstraction is essentially a model creation process that enables solving complex problems by separating logical and physical perspectives. Therefore, abstraction is a key to tackle complexity, making it a valuable skill for the modern world. Moreover, abstraction is actually routinely employed in daily life [15]. Witherspoon et al. found that virtual robotics environments showed evidence of the development of computational practices like abstraction and algorithm development as well as increased interest in computing [11]. Furthermore, we can deconstruct the specificity of the learning dividend into two overall categories. First, we have simpler syntactical and declarative skills, like programming language-specific knowledge. The latter pertains to the acquisition of broader and more generalizable skills. According to Salomon and Perkins, these two categories arise from the existence of two types of transfer: low-road and high-road. Low-road transfer can be accrued over time with repeated practise, until the patterns become automatized. Low-road skills can be applied when sufficiently similar conditions to the practise-scenario arise. High-road transfer require deliberate and conscious abstraction, but yields broader abilities in the student. This implies that students must acquire a decontextualized representation of a principle, in addition to an understanding of the particular situations in which it can be correctly utilized [46]. Through virtual robotics, teachers may be more inclined and able to inculcate high-road transfer in their students.

By representing robotics challenges in a virtual environment, one can also reduce the influence of mechanical errors that often frustrate novices and can distract from basic programming concepts when using physical robots. Instead, virtual robotics enable students to focus on high-road transfer, assuming an intuitive and user-friendly implementation of the platform. It is worth noting that Hartnett mentioned assessment pressure, lack of relevance, and unclear or complicated guidelines as pitfalls that would negatively impact learning in an online context [47]. These pitfalls must be avoided, lest the students perceptions of autonomy, competence and relatedness risk being undermined. To ameliorate some of these issues, Avsec et al. suggested that specific technology training before robotics course may help increase students' confidence in performing tasks and in turn enhance student satisfaction and achievements [48].

When implemented correctly, simulating robot movement within a virtual environment is not only beneficial due to the conducive learning processes, but also accurately reflecting of a common practice of robotics engineers today. Participating in this process provide students an opportunity to learn through participating in the authentic practices of a professional community [49]. Virtual robots are also less expensive than physical ones, allowing the benefits of the curriculum to reach a broader population where the costs of physical robotics curricula can be prohibitive [11]. Furthermore, a study by Liu and Shoop found that students using an earlier version of this technology achieved learning gains in programming content equivalent to students using physical robots, but in less time [50]. This is made interesting by the fact that 68.18% of the papers included in a 2018 review used the physical robotics produced by LEGO, while most schools are unable to provide this expensive robot equipment due to limited budgets [10]. Moreover, LEGO features as non-open robot kits, based on microcontrollers, and with a proprietary programming language. Consequently, the knowledge is less transferable than more widespread and general development tools. Considering the above caveats of LEGO, it could be more desirable to educate robotics using accessible and affordable open source software in the future.

2.4 Research Gap

As imminently apparent by looking at sections 2.3.1, 2.3.2 and 2.3.3, the topics of this thesis do not lack individual research nor proof of their individual usefulness. Still, no research has been done to amalgamate the benefits of design thinking and virtual robotics in education.

Indeed, Razzouk confirms that there has been substantial research on how design thinking can be utilized, mainly to enhance business strategies, but also to facilitate learning. She does, however, state that a current lack in the research body of design thinking is that researchers are yet to examine the effects of the design thinking processes on specific learning outcomes [26]. Jung et al. argue that the diversity of research participants needs to be broadened [39]. Moreover, Tsai and Wang suggested that "*the relationships among design thinking, computational thinking* *and computer programming self-efficacy can be further examined for the development of student's 21st century key capabilities*" [2]. This suggestion is particularly relevant as it relates to design thinking, STEM education and 21st century skills. The systematic literature review published in 2022 by Li et al. also stated that the empirical evidence that supports the effectiveness of "design thinking integrated learning" is still rather limited, and that more research is needed to explore the integration of design thinking with single or multiple disciplines from a wider subject range [23].

Design thinking and virtual robotics provide a unique opportunity to foster 21st century skills by providing students with hands-on, experiential learning experiences that strongly adhere to constructionism. However, there is a need for research to investigate if and how the combination of these two concepts can enhance learning outcomes in different educational contexts. Of the 35 papers that were included from the systematic literature review, only 5 explicitly combined educational robotics and design thinking, of which none pertained to virtual robotics. The lack of previous research on the combination of design thinking and virtual robotics calls for more research on the matter. By exploring the interplay between learning, design thinking, and virtual robotics, researchers can identify effective strategies for promoting student engagement, motivation, and learning. That research might elicit suggestions that could have significant implications for the future of education, helping students prepare for the challenges and opportunities of the digital age. This requires adequate research on specific topics and their concomitant effects on different learning outcomes - an endeavour to which this thesis aims to contribute.

2.5 Goal

The goal of this master thesis is to explore the potential of combining design thinking with virtual robotics in the context of STEM education. The aim is to investigate whether the two concepts can be successfully integrated for educational purposes and provide an initial indication of their potential benefits. The study will employ a mixed-methods research design, incorporating both quantitative and qualitative data collection and analysis techniques. The research will involve a sample of tenth grade students enrolled in a technology and design course, with the aim of exploring their experiences and perceptions of the intervention. Specifically, the study will examine how the integration of design thinking and virtual robotics can promote engagement, motivation, and learning outcome. The findings of the study will provide insights into the feasibility and potential of combining these two concepts, with implications for future research and educational practice. Upon completion of the aforementioned steps, this master thesis aims to contribute to the understanding of the intersection between design thinking and virtual robotics in STEM education and provide a foundation for further research.

3 Implementation

To our knowledge, there were no virtual robotics environments that also integrated design thinking. Therefore, we had to develop this ourselves to investigate how students perceive learning in an educational virtual robotics environment with a design thinking approach. This section presents the platform that was used in this thesis. The source code is open and available on GitHub[1]. Core functionality pertaining to virtual robotics was forked from an open-source repository[2]. Several modifications and additions were made to this forked repository to adequately answer the research question, all of which are documented in this section. The objectives and requirements that motivated our choices for technology selection and modification are included in the first section. The actual technology selection and implementation of our platform is then discussed in section 3.2. Finally, we provide the reasoning for our design decisions in section 3.3.

3.1 Objectives

In order to answer the research question, and thereby contribute towards filling the research gap, the platform has to meet a number of requirements. Overall, it should present a virtual robotics environment, where the participants of the study can interact with a robot. For this study, the environment must also challenge the participants with a problem that must be solved. Data collected on how the participants solve this problem is intended to answer the research question. The specific requirements of the platform emerge from the overall objectives. These are quite general remarks that have to be satisfied in order to collect the data needed for the thesis. First of all, the users need to be able to program, edit and interact with the robot in a virtual environment. Second, it should be possible for them to explore and play around with the platform, and follow a design thinking approach. Finally, their interaction with the platform should generate insightful log data, which needs to be stored for analysis. These objectives are decomposed, expanded upon, and presented in Table 2 and Table 3.

Table 2: Functional requirements for the platform.

ID	Requirement	Priority
FR1	The user should be able to open the platform in their browser	High
FR2	The user should be able to program a robot without extensive prior skills	High
FR3	The user should be able to program the robot with motion and certain actions	High
FR4	The user should be able to use loops and logic in their code	High
FR5	The user should be able to interact with the robot	Medium
FR6	The user should be able to view hints and relevant information	Medium
FR7	The user should be able to edit the robot	Medium
FR8	The user should be able to register with the group's ID	Medium
FR9	The platform should be able to log all of the user's interaction	High
FR10	The platform should store log data on a per-group basis	High
FR11	The platform should allow effortless export of data for analysis	Medium
FR12	The platform should prevent accidental refresh and exit	Medium

Table 3: Non-Functional requirements for the platform.

ID	Requirement	Description	P
NFR1	Usability	The platform must be extremely intuitive and easy to use	H
NFR2	Scalability	The platform must run as intended and without latency with 10 $\leq$ simultaneous users	H
NFR3	Localization	The platform should be adapted to the intended users	M
NFR4	Compatibility	The platform should run regardless of OS and browser	M

[1]https://github.com/KristofferNyvoll/gears-master
[2]https://github.com/QuirkyCort/gears/tree/master/public

3.2 Technology

In order to satisfy the functional and non-functional requirements, there was a need to develop a virtual robotics platform. A virtual robotics platform needed three distinct parts to qualify as an eligible option for this thesis: (i) a simulator, in which the robot is rendered in an environment, (ii) some way of programming the robot, and (iii) some way to make changes to the robot itself. Developing a virtual robotics platform that met all of these requirements from scratch in such limited amount of time, while also allowing active use of design thinking, was unrealistic. Luckily, there existed several viable options that we could base our implementation on. Compatible options had to meet a number of criteria. We wanted a platform that:

1. Pertained to virtual robotics.
2. Was open source.
3. Allowed forking and unlimited zero-cost usage.
4. Was well documented.
5. Did not inhibit implementation of design thinking.
6. Preferably was written in maintained languages/frameworks and reliable packages.
7. Preferably could run in the browser.

The reasoning behind item 1-6 in the list above should be obvious, as they are needed to legally and practically allow the further development that could answer the research question. The reasoning behind the preference regarding browser compatibility is not equally overt. Most, if not all, of the secondary schools in Norway own or hand out computers or tablets that either prohibit or require administrator-access to download and execute proprietary software. This obstacle would make it significantly harder to perform the user testing with a program that must be downloaded and executed compared to a program that runs in the browser. Hence, browser compatibility was preferred.

3.2.1 Gears Platform

After thoroughly investigating nine viable solutions, there was one platform that appeared far more suitable than the rest. Gears, an acronym for "Generic Educational Autonomous Robotics Simulator", is an open-source robotics simulator written in JavaScript and Python. Using tested and reliable packages, it met all of the specified requirements and preferences, without excessive complexity. Basing the core implementation on Gears would allow us to meet the objectives listed in section 3.1 in time before the ensuing user testing. Importantly, since it was written in JavaScript, we could run our platform in the browser, as specified by FR1 in Table 2.

Being able to program and interact with a robot in a virtual environment is the core functionality that must be fulfilled in order to classify as a virtual robotics tool. For simplicity's sake, we kept the default robot used by Gears, which has two wheels, loads of programmable sensors, and some actuators (motors) that could be programmed to perform certain tasks. By using this robot, the participants in the empirical study were supposed to solve a problem we constructed for them, which will be discussed in Section 4.4. In short, the platform had three main tabs: two for programming and one for simulation of the robot. The first of the programming tabs enable one of the simplest forms of programming, namely block coding. It uses a JavaScript library for building a visual code editor called Blockly[3], in which users can drag-and-drop blocks of code and arrange them to form a complete computer program. This code is compiled instantly upon clicking one of the other tabs. In other words, it translates the block code to Python code upon clicking the Python tab, and compiles the code for the simulation when the simulator-tab is clicked. The fact that it used Blockly was highly convenient, as the participants of the empirical study had previous

[3]`https://developers.google.com/blockly`

experience with that exact library, implying zero novelty in that tab and contributing towards FR2. Figure 4 shows an example of how this tab can look. The different categories of blocks are listed in the left menu. In the middle, one can see the specific blocks pertaining to each category, in this case, this is the "Loops"-category. The categories were sufficiently diversified to meet FR3 and FR4. To the right, there is an example of a block code computer program. Figure 4 also displays the three tabs; "Blocks", "Python" and "Simulator" in the upper left corner.

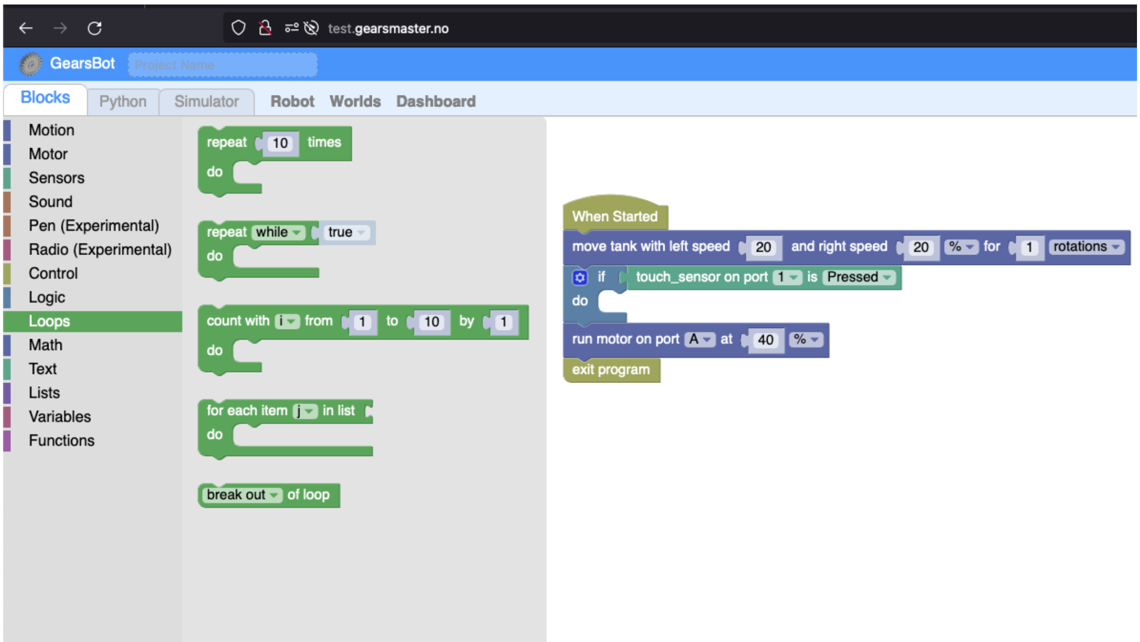


Figure 4: The block coding tab.

The second programming tab is a bit more advanced, as it requires that the users write their code in Python. Compiling this Python-code on the client-side is achieved using Skulpt[4], a system that translates the Python code into JavaScript that can be executed in the browser. An example of the Python tab can be seen in Figure 5. The code on lines 35-39 was automatically generated from the corresponding block code in Figure 4.

[4] https://skulpt.org/

Figure 5: The Python tab.

The final tab uses the compiled code from the other tabs to simulate a robot in an environment, as needed by FR5. The actions and functionalities of the robot is determined both by the code provided by the user, and the robot itself. One could also edit and upload other robots, thereby satisfying FR7. The environment (also called world) that the robot exists in can also be changed. For instance, one could simulate a fire rescue situation by making a world with a building that was on fire, as in Figure 6. This world was used during user testing.

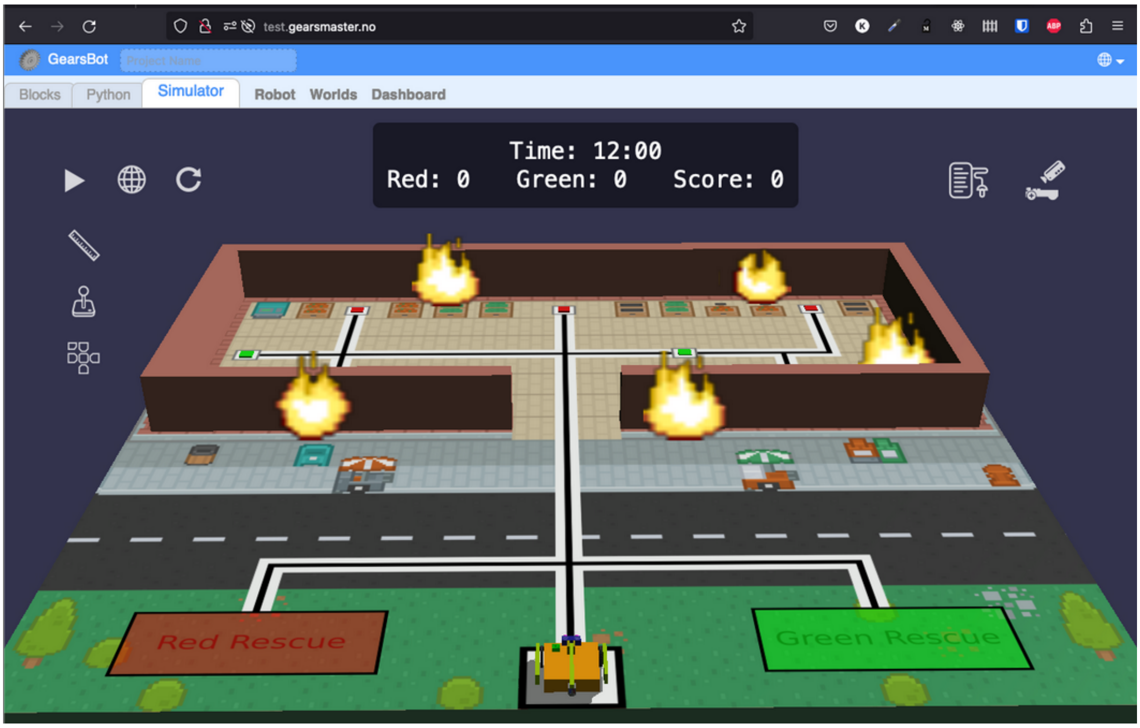


Figure 6: The simulation tab showing the "Fire Rescue"-world.

3.2.2 Features

Despite meeting most of our minimum requirements as the selected virtual robotics platform, the Gears platform could not innately answer the research question. Hence, there was a need to implement several new features that would allow us to subtly guide the participants while using the platform, thus enabling the desired steps of the design thinking approach. Furthermore, we needed to collect log data, remove redundant functionality and tailor the platform for the user testing.

Simulation scenario

The scenario chosen for the activity was a fire rescue mission, as displayed in Figure 6. In this scenario, the robot can initially drive around the game world, but is not able to actively interact with objects, and thus not able to complete the rescue mission. The challenge of the game is to develop code for the robot, using the block coding and/or Python tabs. This scenario was chosen because it has an ill-defined challenge, that the has to be solved by thinking creatively. The simulation for this game world was previously implemented. However, some minor changes was made to adapt the simulation for a design thinking activity. Firstly, the clock functionality was changed to work better with the activity plan. This was done by setting the time limit to eight minutes. The reason for this was to define a time limit that was more suited for the challenge aspect of the activity, and that matched the general time limitations of the prototyping session (one hour). Additionally, the functionality for creating and changing worlds were hidden to minimize the chance of problems caused by students accidentally changing the simulator to another game world.

Informational modal

Enabling autonomy for the students, for example through a dashboard or modal that provides guidelines and self-assessment, can improve deep learning, metacognitive capability, motivation and self-regulation [51, 52]. Moreover, allowing the students freedom and control over their own learning is of paramount importance to facilitate the "21st century skills", as mentioned in section 2. Still, providing useful prompts and guidance during user testing can be used with the intention of keeping the groups focused and pursuing worthwhile goals while still giving them autonomy. FR6 also requires that the users should be able to view hints and get relevant information. Therefore, we implemented a modal that: (i) provided relevant information to the participants to facilitate performance, and (ii) asked calibrated questions that pertained to each step of the design thinking process. By posing those questions, we could induce thought patterns that were likely to ensure adherence to each step. The contents of the modal can be found in Appendix H.

Achieving the two points mentioned above required more text than one ought to present at once to adolescents. To provide perspicuous information pertaining to each step in an uncomplicated manner, we split the information up and implemented navigation in the modal. Less text on each slide can be more motivating than requiring them to read large amounts of text at once [53]. The modal was made easily accessible by the click of a button in the tab menu.

The alternative method of providing guidance and ensuring adherence to the design thinking approach was that the two facilitators could roam the classroom and talk to the groups. This was considered, but found to have two significant weaknesses. First, the groups would likely request, and thus receive, different amounts and detail of information. This, in turn, could affect the quality of the data. Second, we would have lesser control of the structure and delivery of the information, as providing the same exact help to every single group would be difficult and time-consuming.

Log data

Log data contributes to answering the research question by providing insight to all of the participants' interaction with the platform. Furthermore, it was required by FR9. Collecting this information was achieved by implementing "EventListeners" to every relevant component that the participants could interact with. Upon triggering these "EventListeners", the trigger would be appended to the list of all of the tracked data, along with the timestamp. These triggers included:

- Keyboard presses.
- Navigating between tabs.
- Clicking on the different simulator-panels: joystick, buttons, etc.

The log-data-object was comprised of a list of tuples (timestamp and trigger), and was therefore completely anonymous. The only information that could connect the group ID with the names of the participants, was a physical piece of paper in our possession. No other data was collected nor shared with other packages.

3.2.3 API and Data Persistence

The collected data needed to be sent and persisted somewhere. Since the data already was parsed into the desired structure, no further operations were needed before storage. Thus, there were three requirements: (i) setup an API with authentication, (ii) send the data from the platform to this API, and (iii) save the data, so it can be analyzed later. Although this could be accomplished by first setting up a backend with for instance Express.js and MongoDB and then export the data for analysis, this would entail unnecessary complexity and not yield any additional benefit. Instead, we opted for a solution that streamlined the entire process, readily making all the data generated by our user testing available in CSV-format in real-time while simultaneously handling persistence and authentication. Storing the data directly in CSV-format is adequate for FR11. This was accomplished with Google Cloud Platform (GCP), more specifically the Google Sheets API.

The Google Sheet API is quite straightforward. When the platform is opened, two google scripts are loaded (Google API Client and Google Identity Services). These scripts initialize clients that handle the configuration and verification of the client and sending data. Numerous keys and ID's are needed for this step, all of which can be configured in GCP.

As stated by FR8, the user should be able to register with the group's ID. Upon initial load of the platform, we implemented another modal that prompts the user to enter the group ID. We had already assigned each group an ID and authenticated the client to our server before handing out the computers. This ID was used to ensure that we knew which group the data belonged to (across the other data collection methods as well). The platform would still be functional without entering an ID, but the data lacking an ID would not be persisted in a separate sheet. By using an ID, we could unambiguously find the data for each group across sessions and data-types. The callback of this ID-modal invoked a function that authenticated the client with the OAuth 2.0 server wrapped by Google Identity Services (GIS). After this initial setup, the platform was ready for use. Ensuing the authentication, the log data was sent to the sheet that matched the ID entered on setup at a given interval, as required by FR10. This interval was set to five minutes in order to minimize bandwidth usage, while still ensuring that no data would realistically be lost. While it was possible to have everything operating at real-time, this would entail a huge number of requests and yielded no added benefit. This solution was scalable, reliable, and real-time with included storage and authentication through a user associated with this project.

3.2.4 Hosting

We used DigitalOcean for hosting. DigitalOcean offer Droplets, that are simple and scalable virtual machines. A droplet could easily handle multiple simultaneous users, map to our domain and was fully compatible with our server and CORS configuration. In doing so, it satisfies NFR2 and enables NFR4 from Table 3. Comfortably covering all our needs, while still being affordable and requiring minimal configuration, their droplets seemed like a brilliant choice. We also bought a fitting domain that could be used for the user testing through domeneshop.no.

The development was done using Github, where the public repository is readily available[5].

3.2.5 Architecture

Figure 7 attempts to coalesce the technologies mentioned above into a coherent overview. To summarize how it all works, the user visited the url (http://test.gearsmaster.no), which was hosted on DigitalOcean. Note that the platform only was deployed during testing, as constant deployment would be unnecessary and could be costly. The droplet on DigitalOcean was running a JavaScript webapp. The webapp was connected to the Google Sheets API via the Google Identity Services, using OAuth 2.0 for authentication. The data that the user generated through interaction with the webapp was then sent to a spreadsheet using the Google Sheets API, and the anonymous log data was stored on Google Drive.

[5] `https://github.com/KristofferNyvoll/gears-master`

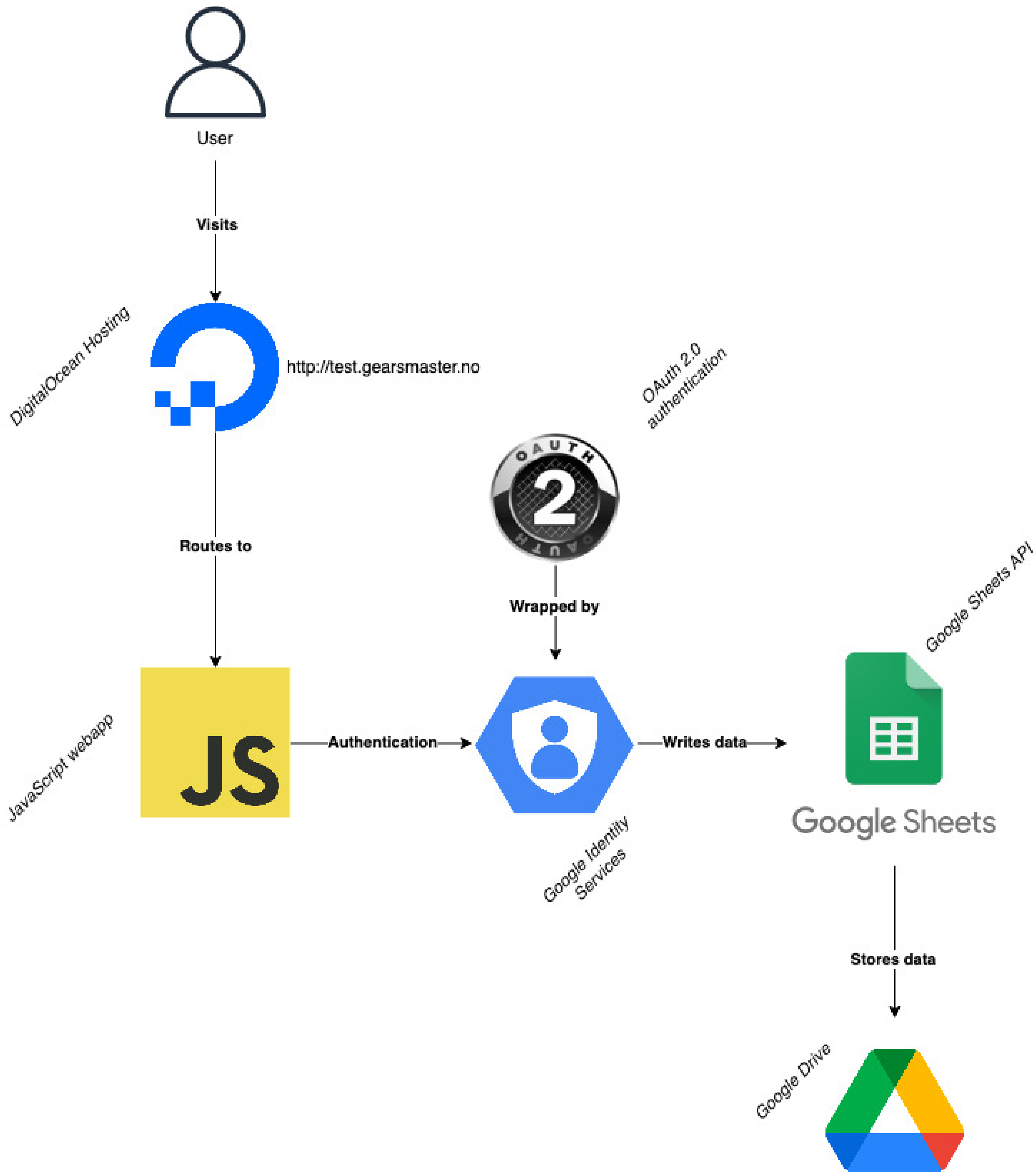


Figure 7: The overall architecture of the platform.

Figure 8 supplements the overall architecture and summarizes which additions we made to the existing code that was forked from the open-source gears repository. The boxes with green borders were added by us, the remainder were largely unchanged from the forked repository.

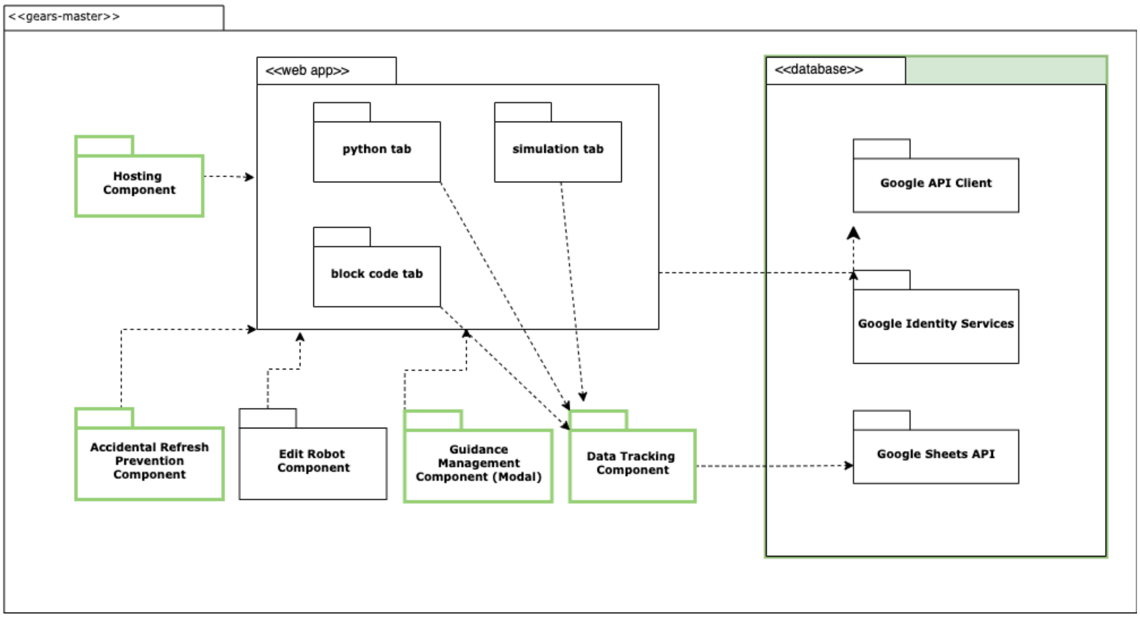


Figure 8: UML component diagram.

Figure 9 shows an example of how a user could interact with the platform, and which functions this would trigger. While some of the actions taken by the user in Figure 9 are awaiting explanation in Section 4.4, the sequence diagram shows the sequence of expected actions taken in the beginning of the second user testing session.

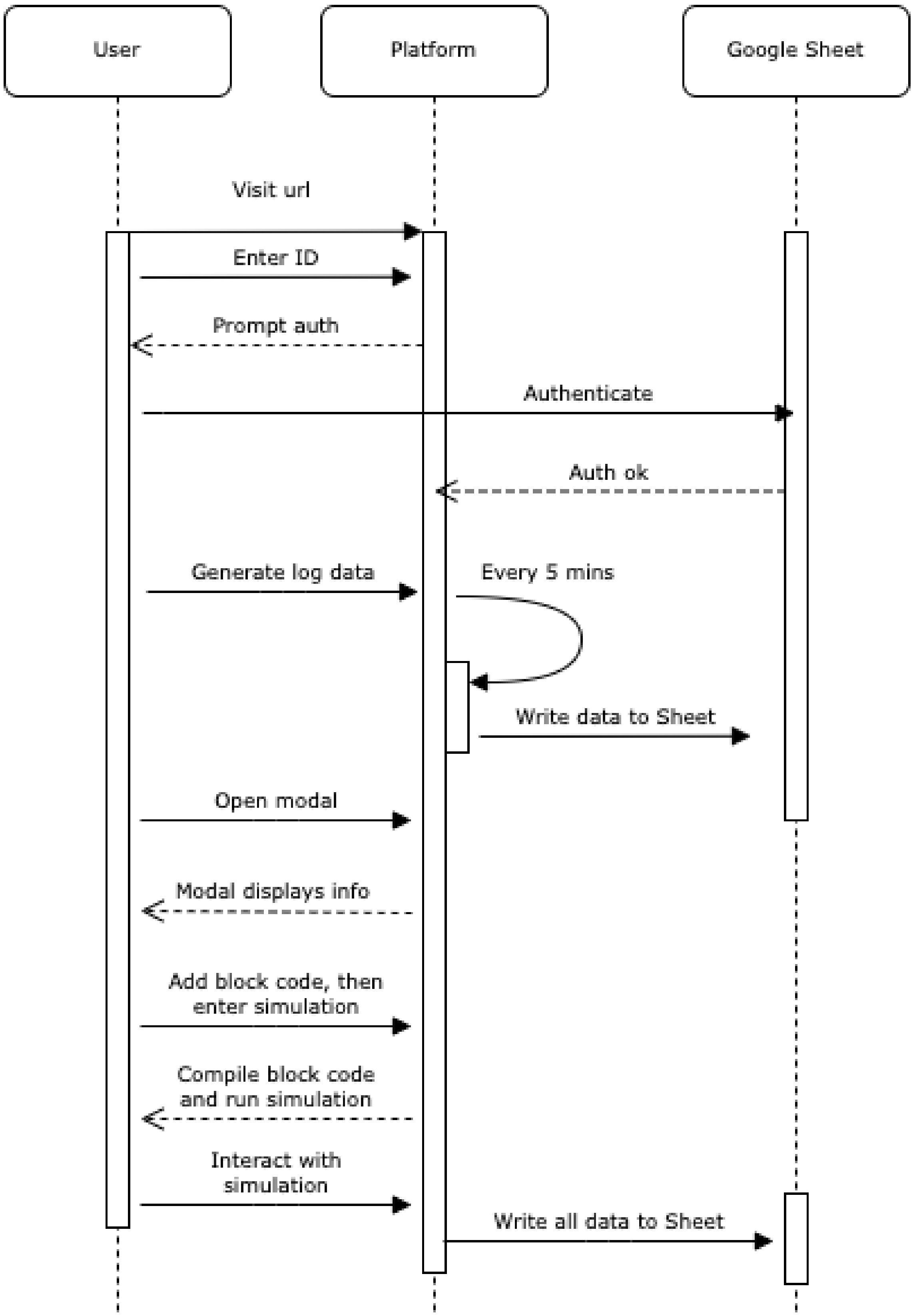
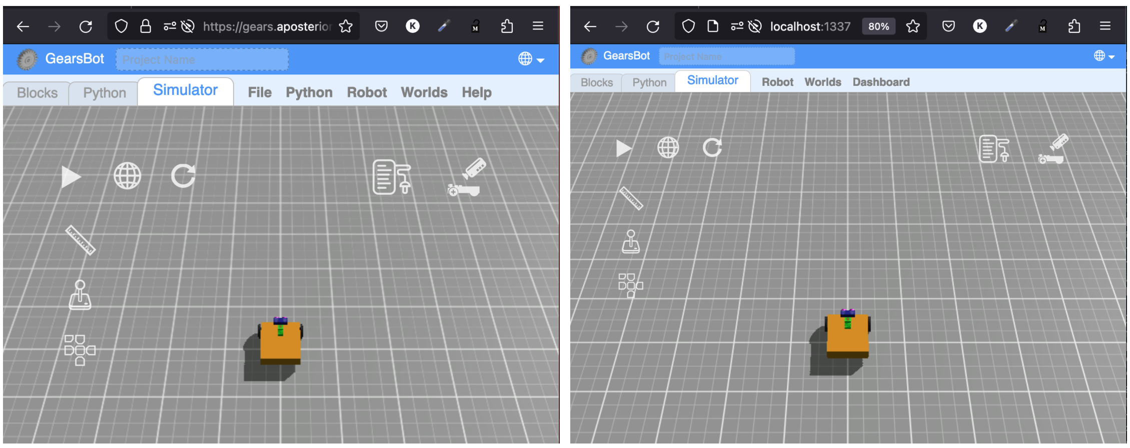


Figure 9: UML sequence diagram.

3.3 Design Decisions

As we shall discuss further in section 4.2, the available time for user testing was limited to two one-hour sessions. Also, the foremost non-functional requirement, NFR1, states that the platform must be intuitive and easy to use. Thus, it was of paramount importance that the design of the platform addressed these requirements. This would ensure that no unnecessary time was wasted on unproductive endeavours, like troubleshooting, mindless navigation and confusion-induced inactivity or apathy. With this in mind, we strived to keep the complexity of the platform as low as possible. This resonates well with the findings discussed in section 2.3.3. Through communication with the teacher early in the implementation-process, we attempted to assess the participants' level of previous experience. The teacher was also involved to create an activity plan that would be engaging for the students and that also took into account their current experience level with block coding and Python from the curriculum. Based on this, and the plan for the two separate user testing sessions, we made specific design decisions that would improve the participants' experience. Additionally, the teacher helped preparing the content of the modal, to ensure the information would be formulated in a helpful way for the students. The participants retained a high degree of focus during both sessions, and they deemed the user interface intuitive overall.

By selectively choosing which parts of the platform that we made available in each session, we narrowed down the number of possible actions that could be made. This was done to reduce the complexity of the platform. Combined with other adjustments, this helped meet NFR3. The pre-existing styling of the platform that we based our platform on was simple and already in line with our requirements (intuitive, user-friendly and easy to use). However, not everything the platform offers in available functionality was needed for the tasks given to the participants in the two sessions. Thus, to facilitate ease of use during the sessions, only the relevant functionality was made available in the platform during each session. Options for file management, settings and world selection was made unavailable for both sessions. For the first session, block coding, Python coding and robot selection/management was also made unavailable. The purpose of this was to simplify the platform in a way that would facilitate focus on the tasks at hand for the given session. The differences in user interface between the forked repository and our modified version can be seen in Figure 10.



(a) Before modification (b) After modification

Figure 10: Some buttons were removed to simplify the platform.

4 Method

This section explains the rationale behind, and execution of, the empirical study, including the data collection and analysis. We start by outlining the overall research design in section 4.1. The research design is followed by a description of the participants in section 4.2. The research design and participants determined the data collection methods explained in section 4.3, which then dictated the procedure outlined in section 4.4. Finally, we describe how the data analysis was carried out in section 4.5.

4.1 Research Design

This study employed a within-subjects approach to investigate how adolescents perceived learning in a educational virtual robotics environment with design thinking. The research question was focused on the exploration of ways to support problem-solving and learning in such an environment. Owing to the restricted number of participants, a mixed-methods design with triangulation was adopted to bolster the credibility of the findings. Multiple data sources, including interviews, questionnaires, log data, and artefacts, were gathered and analyzed to provide comprehensive and insightful data while also examining associations among the various data collection methods.

The within-subjects approach is a research design in which each participant in a study is subjected to all of the experimental conditions or treatments, enabling researchers to draw stronger inferences and reducing the impact of individual differences. Mixed-methods research is an approach that involves collecting and analyzing data using both qualitative and quantitative methods to gain a more comprehensive understanding of a phenomenon. Triangulation, on the other hand, refers to the use of multiple data sources or methods to verify or validate findings, which enhances the rigor and credibility of the research. The use of interviews, questionnaires, log data, and artefacts in this study allowed for a more complete understanding of the participants' perspectives and experiences in the virtual robotics environment, as well as the effectiveness of the selected design thinking approach.

4.2 Participants

Participant recruitment was one of the most strenuous challenges of this thesis. Reaching out to relevant municipalities, like Trondheim and Oslo, proved unfruitful. Friends who worked as teachers were unable to help, and direct inquiries to schools were usually declined or ignored as they were disinclined to donate multiple hours of valuable teaching from their already packed calendar. After the attempted random sampling failed to yield any results, the convenience sampling technique was applied. A friend and principal of a secondary school in Kongsberg approved of our request and set us in contact with the teacher of a "Technology and Design"-class, who courteously accepted our request. This was an elective class, implying that the members of that class had a genuine interest in technology and/or design. One hour each week was dedicated to this class, in which they usually spent 1-2 months on each subject in the curriculum. Through regular classes, including presentations from the teacher followed by the students solving tasks, and projects pertaining to programming, the students were supposed to gain familiarity with technology and design. At the point of our study, the class had previous experience with block-coding through an app called "Microbit" and were familiar with Python, removing the need for detailed training on the technological aspects in the user testing. They also had some basic knowledge of HTML and CSS. The pretest questionnaire included questions regarding their previous experience with programming, robotics and design thinking, where programming predictably had the highest mean value. More on these results can be found in Table 11. The students of the class were 15-16 years old.

A total of two sessions was allocated to the user testing. Those two sessions lasted an hour each and were two weeks apart. The class consisted of 16 students, of which 15 participated in the first session. For the second session, six students were on a field trip and three were absent due to illness, leaving a total of eight students available for the second session. We were informed of the absence due to the field trip one day before the first session, and were therefore able to organize the groups thereafter. All of the eight students that participated in the second session also participated in the first session, and they continued in the same groups. For the first session there were three groups with three students and three groups with two students. In the second session there were four groups with two students. Consequently, all data collected from the first session was gathered from six groups, while all the data collected from the second session was gathered from four groups. Only two of the students were females, and they participated in both sessions. The rest of the participants were males.

All participation in this study was voluntary, and it was clearly specified that participation would not in any manner affect their grades in the course. Communication with the participants prior to the study was done through the teacher. They were informed of the ensuing two sessions by their teacher a week before the first session. The teacher also handed out written consent forms that had to be signed by their parents or legal guardians and returned. The consent form contained information about the project, as well as the participant's legal rights regarding the usage and protection of the data generated through the user testing. It can be found in Appendix D. Issued and approved by Sikt (Norwegian Agency for Shared Services in Education and Research), this form prompted the parents' or legal guardians' consent on our collection and analysis of data related to this study.

4.3 Data collection

Data was collected through interviews, questionnaires, and the user testing itself, which generated log data and artefacts. The following sections explain the concomitant methods in greater detail.

4.3.1 Questionnaires

Pretest and posttest questionnaires were given to the participants before and after the user testing, respectively. These questionnaires aimed to gather data regarding perceived learning and motivation, as well as experience with and attitude towards STEM subjects, virtual robotics and design thinking. The questionnaires consisted of Likert scale questions, and some additional free text questions in the posttest questionnaire. All the collected variables can be found in Table 4 and 5. Both were made using "Nettskjema", a service with a signed data protection agreement with NTNU. The students answered individually on their iPads. The questionnaires can be found in Appendix A.

Table 4: Variables collected in the pretest questionnaire.

Variable	Value	Description
prev_exp_programming	{1,7}	The respondents' level of experience with programming.
prev_exp_robotics	{1,7}	The respondents' level of experience with robotics.
prev_exp_design_thinking	{1,7}	The respondents' level of experience with design thinking.
interest_robotics	{1,7}	The respondents' interest of learning more about robotics.
interest_design_thinking	{1,7}	The respondents' interest of learning more about design thinking.
motivation	{1,7}	The respondents' motivation to complete the user test.

Table 5: Variables collected in the posttest questionnaire.

Variable	Value	Description
understandable	{1,7}	The respondents' opinion on how understandable the tasks were.
exciting	{1,7}	The respondents' opinion on how exciting the user testing was.
fun	{1,7}	The respondents' opinion on how fun the user testing was.
learning	{1,7}	The respondents' learning dividend.
repeat_interest	{1,7}	Interest of doing more of this in the future.
easiest	text	The part of the user testing perceived as easiest.
hardest	text	The part of the user testing perceived as hardest.
expl_design_thinking	text	The respondents' explanation of design thinking.
expl_virtual_robotics	text	The respondents' explanation of virtual robotics.

Questions regarding interest, ease of use and learning outcome were adapted from Davis' study on perceived usefulness, ease of use and user acceptance in information technology [54], while questions regarding previous experience and were based on Holden and Weeden's paper on the impact of prior experience with coding in relation to information technology courses [55].

4.3.2 User testing

We managed to conduct two separate sessions of user testing. Aside from the questionnaires that were handed out before and after the user testing and the interviews, two main categories of data were collected through the user testing itself: log data and artefacts. Artefacts include written materials during the first session, and the final state of the block-coding after the second session. The log data captured relevant user interaction with the platform, including:

- Keystrokes.
- Starting and resetting the simulator.
- Navigation between the different tabs.
- Interaction with the joystick (used to drive the robot).
- Interaction with the button-panel (could be programmed to perform tasks).

The log data was persisted using the Google Sheets API, and is analyzed in section 5.3. The participants were informed that data on their interactions would be collected in an information letter three weeks prior to the second session, but not in exactly which manner. Reduction of Hawthorne Effect is the basis for omitting this exact information, as people tend to behave differently when they become aware that they are being observed. We extracted several variables from the log data, as seen in Table 6.

Table 6: Variables collected through the log data (per group).

Variable	Value	Description
triggers	$0 \leq$	Number of interactions with the platform.
simPanel	$0 \leq$	Number of times the group navigated to the simulation-panel.
blocksPanel	$0 \leq$	Number of times the group navigated to the blocks-panel.
pythonPanel	$0 \leq$	Number of times the group navigated to the python-panel.
runSim	$0 \leq$	Number of times the group ran the simulator.
resetSim	$0 \leq$	Number of times the group reset the simulator.
stopSim	$0 \leq$	Number of times the group stopped the simulator.
arrowKeys	$0 \leq$	Number of times the group controlled the robot with the arrow-keys.
wasdKeys	$0 \leq$	Number of times the group controlled the robot with the wasd-keys.
toggleJoystick	$0 \leq$	Number of times the joystick was selected.
resetJoystick	$0 \leq$	Number of times the joystick was reset to origo.
backspace	$0 \leq$	Number of presses with the "backspace"-key. Used to delete blocks.
toggleHubButton	$0 \leq$	Number of times the hub was selected.
hubButtons	$0 \leq$	Number of times any of the hub buttons were clicked.

During the first session, the participants were instructed to write down all of their thoughts and reflections during the first two steps of the design thinking approach. This was done with the joint intention of supporting the log data with additional insights on the design thinking approach and making the participants formulate their thoughts to increase retention of knowledge. In addition, three participants collaborated on one computer, so allowing them to also write down their thoughts on paper would increase total activity within the groups.

Involvement from us and the teacher during user testing was based on the advice of Sisman et al. They observed that once the teacher only corrected the mistakes of the students (at the students' request, adhering to the philosophy of student-centered feedback), the students reflected on how their robot worked, which increased learning. This demonstrates the importance of teacher guidance and intervention at appropriate times [56].

Xia and Zhong extracted several useful suggestions for user testing from the 22 papers included in their systematic literature review on educational robotics in 2018 [10]. Of these, we strived to incorporate the three that were most applicable to our user testing procedure: spaciousness, adaptations and content design. Regarding spaciousness, they recommended large and open classrooms to facilitate more open and creative behaviour. The classroom we used during the sessions had capacity for more than double the number of participants, and had seating arrangements that enabled cooperation without overly noisy ambient sounds. The second suggestion, adaptation, involves specifically designing hardware and software for the intended audience, such that everything is appropriate. The participants carried out the user-tests on the school's MacBooks, and the block-coding implementation was based on Blockly, both of which the participants were already familiar with. Content design is the final suggestion we strived to achieve. Xia and Zhong explain that the link between robotic activities and everyday life is important. Therefore, we gave the participants a task that was easy to understand and has real-life inspiration. Moreover, it comes from a scenario that everyone has basic understanding of, while simultaneously very few have given any conscious thought. As a result, they immediately grasped the scenario and knew what the overall problem was.

4.3.3 Interviews

The participants were interviewed immediately after the posttest questionnaire. This interview sought to collect their opinions on the sessions and platform. We also wanted to elicit self-assessment and reflection on their performance and perceived learning in these interviews. Asking them to reflect on this in a questionnaire would steal too much time from the prototyping, and allowing them full freedom of speech was thought to incite maximum openness. Large and open rooms were used for the interviews, and we only dedicated one interviewer for each interview with the intention of making the interviewees comfortable and more inclined to articulate their thoughts freely. With their consent, the interviews were audio-recorded, thus enabling the interviewer to solely focus on the interview itself. We followed a semi-structured interview style based on the Interview Guide in Appendix B. There were minor deviations and follow-up questions when we had opportunities to gain additional valuable insights outside of the interview guide.

The interviews were conducted in the same groups that cooperated during the user testing, due to time-constraints and higher probability of participation. All the groups participating in the second session were interviewed. During the user testing they showed great display of cooperation and playing on each others' strengths, which also was the case during the interviews. Still, conducting group interviews can introduce certain biases. Since we knew of this in advance, we could prepare ways of ameliorating these biases. Before we began, we ensured that both interviewers were aware of the observer bias, so that we could strive to mitigate the influence of our own perception in how we interpreted their answers. This bias was also kept in mind while constructing the interview guide. Next, we made sure that the interviews were as relaxed and safe as possible, by using humour and informal communication before initiating the interview without any clear or abrupt transition. Also, the mobile device that recorded the interview was casually placed out of focus, with the screen down. Both of these measures were taken to mitigate the interviewees' perception of being observed. Participants' ability to accurately recall the events of the user testing is likely to degrade over time, which can be a problem in retroactive data collection. Since the interviews were conducted immediately after the second session, which was the primary focus of the interviews, the elapsed time is unlikely to have had any adverse effect on the quality of their recollection.

4.3.4 Artefacts

To provide further insight to potential findings, we also collected valuable artefacts after both sessions. During the first session, the participants produced varying amounts of written notes pertaining to the first two steps of the design thinking process. They were instructed to write down all of the thoughts they had, and also to briefly answer the calibrated questions in the modal. These questions were designed to guide the students through the process of completing the *discover* and *define* steps of the Double Diamond-model. The modal provided guidance on how to perform brainstorming, exploration and information collection related to the problem, and then how to define proposals of improvement, presented in four different pages of the modal. Each of these pages asked open ended questions to help the students in their thought processes, and can be found in Appendix H. The notes taken by the students mainly pertained to these questions. Consequently, the notes taken were mostly related to how the robot works, challenges related to the fire rescue scenario and which improvements can be made to the robot to optimize outcome. Naturally, some unrelated notes were also written down during the session. In the printed research material, which was based on Oates's description of "researcher-generated documents", they were also instructed to underline anything they found particularly interesting or important [57]. Lastly, we also include screenshots of the final block-code as an artefact. These provide perspicuous evidence towards how close the groups came to a viable solution.

4.4 Procedure

The procedure outlines all the steps that the participants underwent in the process of user testing. Every part of the procedure was thoroughly planned beforehand in order to ensure efficient data collection.

4.4.1 Preparation

Initial planning of the procedure began two months prior to the user testing. The teacher of the class helped assess the students' knowledge and competencies, such that the user testing could play on their strengths and accommodate any gaps in prerequisite knowledge. Moreover, the teacher provided suggestions on optimal group formation. Insights gained from the collaboration with the teacher made it possible to tailor the plan for user testing to the participants. For example, they had used a block-coding tool called Microbit before, and were thus familiar with the exact same block-coding library that we used in this project. Therefore, the block-coding needed no further introduction, and valuable time could be spent elsewhere in the first session. The preparation resulted in an efficient activity plan, which describes every aspect of the user testing in great detail, and can be found in Appendix C.

As mentioned in section 4.2, the participants were informed of the ensuing research collaboration and handed the consent forms a week prior to the first session.

4.4.2 First Session

We visited the school to conduct the user testing in person. Upon arrival, we used the time before the session to prepare the computers we borrowed from the school for user testing. When the session started, we introduced ourselves, the research project and the plan for the day. Then, we gave a short lecture on design thinking and virtual robotics. The majority of our emphasis was put on the usability of design thinking and the specific steps. In other words, we told them *why* and *how* to use it. The participants were organized into groups of three, ensuring that at least two members of each group would be present during the second session where some were expected to be absent due to a field trip. Also, design thinking benefits greatly from cooperation, and teamwork was deemed as more motivating than working in solitude. Multiple minds also tend to generate more ideas, which supports the need for creativity in problem solving. Moreover, the participants were used to collaboration in this class.

Then, the participants were asked to answer the pretest questionnaire, which was described in section 4.3.1. When everyone had submitted the questionnaire, the computers were handed out, and the user-test commenced. Along with the computers, we also handed out the printed research material in Appendix E and blank paper that the participants were instructed to use to write down any thoughts they might have while following the design thinking process. The printed research material is the only pre-made material used in the study, obviously apart from the developed platform. Naturally, the design of the sessions was based on the relevant literature. Double diamond, the selected model for this user-test, has four steps: *Discover, Define, Develop and Deliver*. The first session focused on the first two steps, while the two remaining steps were covered in the second session. This separation was done intentionally. Being an inherently open and creative endeavour, design thinking can be overwhelmingly ambiguous for beginners. Therefore, focusing their efforts on the first two steps was assumed to help the participants begin, and would also ensure that the participants iteratively diverged and converged on their ideas. Furthermore, preventing the option to immediately develop their solution is critical for adherence to the first steps of the design thinking process, as stated by Vossen et al.: "*some students prefer to skip research and start building their design right away*" [58].

The participants worked on the two first steps, *Discover and Define*, in the first session. The *Discover*-step revolves around understanding what the problem is and the needs of the users, as well as gathering relevant information. Simply asking the participants to make changes to the robot would be too open, and probably yield varying results between the groups. In other words, they needed a problem to solve. Therefore, we made a fictional problem that was simple to understand, yet open and ill-defined, with many possible solutions. One of the worlds designed in the platform is called "Fire Rescue", in which eight objects are placed in a burning building. Their task was to save the objects from the fire. Regardless of previous education, everyone has some inherent perception of what happens during a fire, along with the dangers and consequences. Fire rescue therefore seemed perfect, providing a problem that would need little introduction, and with many viable solutions. First, the participants were to familiarize themselves with the platform, and collect information on the subject of fire rescue. They received an abundance of printed information on the subject, and were therefore forced to prioritize how to efficiently allocate their time. The printed information can be found in Appendix E. In summary, it pertained to some of the potential advantages and disadvantages of using robots in fire rescue, how a robot can be used, and loads of information on fire rescue itself. While the printed information could provide inspiration, the modal of the platform contained calibrated questions and prompts intended to incite creative thinking in the participants, as well as ensure adherence to the design thinking model. These calibrated questions and prompts were thus meant to subtly guide the participants through the *Discover*-step. A full overview of the content of the modal in both sessions can be found in Appendix H. Two examples of calibrated questions from the first session (translated to English) include: "What could go wrong during fire rescue?" and "Which problems with human fire rescue can a robot fix?". The modal could be accessed by clicking a button in the header, clearly visible and accessible at all times. Opening and closing the modal had no adverse effects on the other parts of the platform, and the participants got used to interacting with the modal during the first session. Following the activity plan in Appendix C, we clearly announced progression to each new step in the Double Diamond model, and reminded the participants that they could find valuable help in the modal (called "Dashboard" in the platform). As mentioned in section 3.2.2, the participants could use arrows to navigate through the different slides in the modal. The participants were instructed to write down their notes and underline any particularly insightful parts of the distributed printed information. In this step, the participants generated loads of ideas and worked creatively to define and better understand the problem. In the final portion of the first session, which pertained to the *Define*-step, the groups were asked to succinctly describe minimum two specific areas to focus on or problems that could be solved. These would form the foundation for the next session. A complete and more in-depth overview of all the activities in the first session can be found in Appendix C.

Although the participants interacted with the platform in this session, the main focus was to gain familiarity with the problem, do research, and generate ideas. The platform aided them in this, and they were encouraged to play around with the robot and make themselves comfortable with the platform.

4.4.3 Second Session

The second session commenced two weeks after the first session. In this session, the participants performed the last two steps of the Double Diamond method: *Develop* and *Deliver*. *Develop* encourages participants to create multiple answers to the clearly defined problem from the previous step. This usually involves co-creating, seeking inspiration from others, and creative problem solving. The participants developed ideas on how they could modify or program the robot to solve the problem, which could then be tested and improved in the *Deliver*-step.

To initialize the second session, we summarized what had been done two weeks prior. Then, we held a quick introduction to the final steps of the design thinking process, and explained the plan for the day. Immediately after, they were handed the same computer as in the last session, and were asked to start working on a solution to the problem or problem area that they found in the *Define*-step two weeks prior. This was done by implementing block code or Python code (all the groups opted for using only block code) from scratch that would be run in the simulator, adding functionality to the robot on top of the generic movement controls. With numerous reminders and appeals, we attempted to inculcate a mindset of "trying and failing" in the participants, ensuring that they refrained from investing heavily in one idea without quickly testing it against other ideas. Aside from the quick introduction, the rest of the time was dedicated to intense work with the platform. Adhering to the nature of constructionism, the groups were motivated to work independently and learn by trying to find solutions themselves.

At the end of the second session, the participants answered a posttest questionnaire. Participation in the ensuing interviews, which were conducted after the second session was over, was also voluntary, yet everyone participated. The interviews lasted between 15 and 20 minutes, and each participant was awarded a gift card of NOK 150 for their efforts.

4.5 Data Analysis

The data that was collected through the steps described in the previous section had to be analyzed according to certain methods. The methods we followed for the data analysis are elaborated on in sections 4.5.1, 4.5.2, 4.5.3 and 4.5.4.

4.5.1 Interviews

The recorded interviews were conducted in Norwegian, since it was the native language of the participants, to optimize their ability to articulate their thoughts. Therefore, the interviews needed to be transcribed and translated before the data analysis could commence. To ensure sufficient quality and accurate translation, this was done manually. The interviews were then coded to identify reoccurring themes throughout and across interviews. Significant themes will be elaborated on in section 5.

Inductive analysis is an analytical approach where themes and patterns emerge directly from the data itself, without preconceived theoretical frameworks or pre-established coding structures. It involves a systematic and iterative process of coding and categorizing the data to develop theories and concepts grounded in the participants' perspectives and experiences [59]. Regarding analysis technique, we opted for a thematic analysis [60]. This technique involves identifying themes and patterns in the data that emerge from the participants' experiences, rather than imposing a pre-existing theory or framework onto the data. The goal of this analysis was to generate new insights and understanding about the participants' experiences, and to identify commonalities and differences across participants.

To begin the analysis, we read and re-read the transcripts several times to familiarize ourselves with the data. We then started to identify initial labels that capture the content of the data in a concise and descriptive way. Again, an inductive approach was used to identify labels, meaning that the labels emerged from the data itself rather than being imposed by us. As more labels were identified, we refined our coding framework accordingly.

Once we had a comprehensive list of labels, we began organizing them into themes. We looked for patterns and relationships between the labels, grouping them together based on their similarity in content and meaning. We then reviewed the themes to ensure they accurately reflected the data and made revisions as needed. The revisions were done by re-reading each interview several times while marking quotes pertaining to reoccurring topics, before categorizing these quotes and comparing them to the existing themes. This was also done with an inductive approach, meaning that the themes were identified based on the context of the quotes. Finally, we wrote up our findings, presenting the themes with supporting quotes from the participants to illustrate each point. The findings are presented in section 5.1.

To ensure that the thematic content analysis was conducted with sufficient validity, we performed a inter-rated reliability test. Cohen's kappa is typically used to assess the degree of agreement between two or more coders or raters when assigning thematic codes to qualitative data. Calculation of observed agreement (Po) and expected agreement by chance (Pe) was completed before entering these values into the formula for Cohen's kappa:

$$(Po - Pe)/(1 - Pe)$$

For the thematic analysis of the interviews, this yielded an inter-rater reliability of 0.82.

In summary, the thematic analysis we conducted followed an inductive analysis approach by allowing the themes to emerge from the data. The analysis began with a discovery of all relevant labels, followed by organizing the labels into themes. The final step was writing up the findings, using participant quotes to support each theme. This approach was used to ensure the findings were not skewed by pre-established assumptions based on literature or observations, and allowed us to generate new insights and understanding about the participants' experiences and to contribute to the existing knowledge in the field. This thorough analysis approach allowed us to gain significant insight into the perception of the participants, how they approached the tasks, which themes and concepts they focused on in the different stages of the sessions, and how these elements differed between the groups.

4.5.2 Artefacts

To facilitate analysis, we transcribed and digitized the notes and underlined research material. We then conducted a thorough read-through of the digitized artefacts to gain an understanding of the general themes and patterns that emerged. This allowed us to familiarize ourselves with the data and identify preliminary codes and categories.

We then employed a qualitative content analysis approach to systematically code the artefacts according to the identified themes and patterns. This involved assigning labels or codes to specific parts of the artefacts that related to particular concepts or themes that emerged from the data. This enabled us to systematically analyze the data and identify the most relevant themes and patterns that emerged from the artefacts.

To enhance the credibility of our findings, we then used thematic analysis to organize the coded data into overarching themes, in the same manner as was done for the interviews. This allowed us to identify the most significant themes and patterns that emerged from the artefacts and to provide a more comprehensive understanding of the data. By organizing the codes into themes, we were also able to explore the relationships between the themes and identify any patterns or trends that emerged.

By using Cohen's kappa, an inter-rater reliability of 0.78 was calculated for the analysis of the notes and research material.

Regarding the screenshots of the final state of each groups' block-code, we constructed a standardized way of assessing their score. This was important, as it gave us a way to evaluate performance of the prototyping that could be compared to other factors, such as perceived learning outcome. First, we identified how each group intended to solve the problem. The results will be presented in detail in section 5. Figure 11 shows a proposed solution to the most common approach applied by the participants, in which two buttons are programmed to pick up and release the objects.

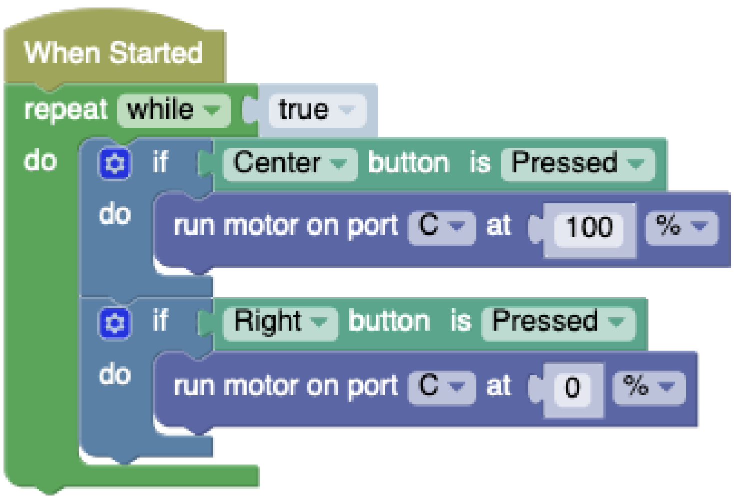
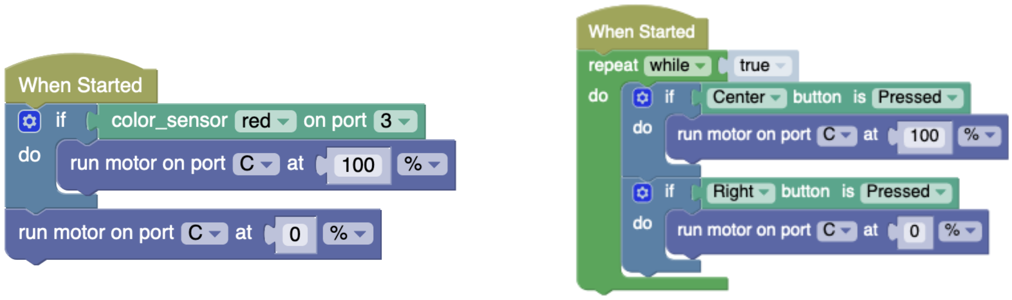


Figure 11: Proposed solution

To give each group a score, we assessed how close they were to achieving a working implementation of their intended solution. The closeness was determined by the number of steps required to make their code "operational". "Operational" was defined by the ability to solve the problem of rescuing the objects from the fire. The less steps, the better, as a low number indicates that they were close. As an example, we examine Figure 12. The number of changes one has to make to the proposed solution in Subfigure 12a to transform it to a working solution, as in Subfigure 12b (identical to Figure 11), is five:

1. Add an outer while-loop
2. Remove the wrong if-condition
3. Add a correct if-condition
4. Add another if-block around the bottom motor command
5. Add a correct if-condition to the if-block in 4)



(a) Example of a proposed solution

(b) Working solution

Figure 12: An example of how scores were calculated.

Each addition, move and removal of the blocks increments the score. We also examined whether the groups had any interesting thought patterns that could be observed solely from their block-code.

4.5.3 Log data

To begin, we wrote a Python script to extract descriptive statistics from the log data. This involved calculating metrics such as the number of key presses, button clicks, and navigation actions per group and per session. We also examined the timestamps in the log data to identify any patterns or trends in interactions over time. A shortened version of the Python script can be found in Appendix F.

Mean values and standard deviations were compiled across the four groups that participated in the second session. As the intense prototyping took place in the second session, that data is more comprehensive as the number of interactions per group was significantly higher compared to the first session, where the main focus was on research, ideation and familiarization. Charts with the most insightful data points were complied to visualize the data.

Then, we did independent samples t-tests, in which one compares the means of two groups that are not related to each other [57]. Since we did several statistical tests simultaneously on the same data set, we also utilized a Bonferroni correction. The t-tests were performed with a Bonferroni correction to adjust the p-values obtained from multiple hypothesis tests to control for the increased risk of Type I error (false positive) due to multiple comparisons. T-tests were used in this way because we wanted to see of there was any significant differences between groups in how they interacted with the platform.

Principal Component Analysis (PCA) is a widely used technique in the field of data analysis, particularly in reducing the dimensionality of large data sets while preserving the essential information. The purpose of performing a PCA is to identify the underlying patterns or structures in the data, which can be used to explain the majority of the variance in the data set. For example, if one of the groups were largely responsible for the variance, a PCA would provide unequivocal evidence for this.

4.5.4 Questionnaire

The questionnaires consisted of two types of questions, namely Likert scale questions with a range from 1 to 7 and qualitative questions with free text answers.

For the analysis of the Likert scale questions from the pretest questionnaire, we found the descriptive statistics and Pearson's correlation coefficients between the different variables. These variables included interest in, and experience with, programming, robotics and design thinking. Correlation coefficients can be useful to find patterns if any data points in the data set are positively or negatively correlated. These methods were primarily selected because we wanted to explore central tendencies and assess the variability of the collected data.

For the free text answers, a thematic analysis was performed in a similar fashion as the interviews and written artefacts. The process started by thoroughly reading through all the answers several times, which gave a clear impression that the themes protruding form an analysis of the content would constitute greater significance if presented in relation to the questions they pertained to. Consequently, the thematic analysis was performed on each question separately, with a less extensive coding and thematization being performed for the answers given to each question. This decision was made because the questions generally pertained to different topics, and exploration of similarities and differences between the answers given to each specific question was of more value than to gain a more general overview of reemerging themes.

A Cohen's kappa of 0,88 was calculated for the inter-rater reliability of the analysis of free text answers.

5 Results

This section contains the results that followed from the data analysis of the interviews, artefacts, log data, and questionnaires. The results pertaining to each data collection are presented in their according section. Finally, we point out some connections in the data across the groups and different data types, which are further discussed in section 6.

5.1 Interviews

In this section, we present the findings from the conducted interviews. The interviews were conducted in the groups that worked together during the second session, for a total of four conducted interviews. The results presented emerged from the data analysis of the interviews, as described in section 4.5.1. The salient emerging patterns were organized into themes, according to the thematic analysis. These emerging themes pertain to *usefulness of the platform, reflections on the design thinking approach, fun aspects of the study* and *learning outcomes.* While the original interviews were conducted in Norwegian, quotes have been translated to English for presentation purposes.

5.1.1 Usefulness of the Platform

The most significant of the emerging themes was regarding the usefulness of the virtual robotics platform. The interviews provided several answers indicating that the platform was both fun and easy to use. When participants were asked what they liked about the platform used in the sessions, one of the interviewees answered;

> *"...It was quite intuitive. It was easy to find things, and it wasn't like we had to ask you for help. We only asked when we didn't understand how to implement something, but we understood the whole platform..."*

When asked about the usefulness of the platform for educational purposes, one student said;

> *"...Everything we have talked about - programming, collaboration and communicating with friends, design, thought processes, everything. Everything is used to make this program. When working two and two, you can also reflect and figure out together how to make the robot better. It's relevant for the future as well, because technology is getting more and more advanced, so we need more and more people which are competent in programming..."*

The partner followed this statement up with;

> *"...Just to say it in short terms, what can this platform be used for? Everything. Design, logical thinking, reflection, cooperation, etc."*

On the same question, another group answered the following;

> *"...It was a quite simple world, so it wasn't difficult to understand what was what. You could see the fire clearly, you could see the building clearly and those blocks you were supposed to extract. So everything was rather simple to understand. I don't really think there is much to improve..."*

One of the interviewees from a third group pointed out that the platform had an engaging element to it;

"...I noticed that I got to utilize skills that I don't use often. I think that's a very nice way to create engagement among the students, because you get to do more than when you are just sitting down and writing. You will also get a better understanding of how everything is connected. If you make a change somewhere, it will cause changes in other places..."

Although the responses were mostly positive, several students also expressed improvements that could be made to make the experience of using the platform better. The suggested improvements were mostly regarding the controls of the robot in the simulator. When asked what they disliked about the platform, one group of students answered the following;

"...The way to control the robot..."

"...When we had to steer the robot, it was very difficult. When you pushed the steering forward, it wasn't actually forward, it was just forward in the direction the robot was facing. That was very confusing..."

Another student agreed, and also expressed a wish for better utilisation of the keyboard;

"...That control you used for the mouse and those buttons, they overlapped each other. That was a bit annoying. I would also have preferred if you could use the keys W, A, S and D to move the robot, and then you could have other buttons, like up, down and to the sides to activate things. Then you wouldn't have to use the touch pad. It would have been much easier with a mouse, but it was mostly how to control the robot..."

Overall, there was a significant focus on the usefulness of the virtual robotics platform, which was deemed both fun and easy to use according to the participants. They also liked the platforms clarity and self-sufficiency, requiring minimal assistance. They praised the platform's usefulness for educational purposes, encompassing programming, collaboration, design, and critical thinking. The platform was considered versatile, covering additional areas such as design, logic, reflection, and cooperation. However, students suggested improvements in robot controls, finding the steering confusing and desiring better keyboard utilization for easier navigation.

5.1.2 Reflections on the Design Thinking Approach

Design thinking was the second significant theme to emerge from the analysis. Several elements of the design thinking steps included in the user testing were referred to in the interviews. One of these elements was the research task the students did during the discover step. When asked about what they enjoyed during the user testing, on group answered the following;

"...I liked the first session, because it was very exciting to read about the robots in context of fire rescue. We didn't have time to read everything, because there were a lot of texts, but what we read was quite exciting...."

"...Yes, I agree with that, and I also enjoyed writing down our thoughts and opinions, and to answer those questions we were given in the modal..."

"...Yeah, which improvements could be made and stuff like that."

When asked about which parts got easier during the sessions, the same group also referred to the research task;

"...Maybe in the first session, when we were answering those questions. When we got to reflect on a question, it gave us more ideas that could be useful for later questions..."

> *"...Yeah, we kind of got into the flow of the topic. So I think it was really great that we started by thinking about the topic and reading texts, because it helped us get into the topic and understand it better..."*
>
> *"Mhm, and to answer questions, because then we had already thought of more ideas without really realizing it..."*

Another group expressed that the discover and define steps done in the first session generated significant value for the prototyping done in the second session. When asked which solutions they tried to implement, one of the students answered the following;

> *"...A lot! We tried several different things. So first off: in the first session, we thought about a lot of things that we could try to implement. Different ways to change the robot, and we thought about adding two more wheels to improve how to control and drive the robot..."*

They expressed continued appreciation of the different steps of the design thinking process when asked about which of the two sessions they enjoyed the most;

> *"... I think the first session was the most fun, because then we were planning what to do. We spent a lot of time trying to figure out how to make the robot better. I really enjoyed the design phase. I also enjoyed the prototyping, and thought that was fun as well. I just wished we had more experience with programming, so we would be able to improve it more. We haven't learned that much about that part yet, so we didn't have that much knowledge to go on..."*
>
> *"...I actually think the second session was the best, because it was much more activity. When it comes to the first session, we got enough information to design. When we finished the design, we were ready to start prototyping. The designing took a bit more time than expected, because there was a lot of information to address..."*

However, not everyone expressed the same enthusiasm for the design thinking steps performed during the sessions. The issues stated were regarding time limitations and lack of excitement for the task at hand. When asked about what they disliked, one group of students expressed that they did not have enough time to perform the discover and define steps properly;

> *"...I remember that in the first session, we didn't have a lot of time to think about a question before we had to move on to the next one..."*

When later asked about which of the two sessions they preferred, the same group pointed out both time limitations and work preferences as reasons to why they preferred the second session;

> *"...I preferred the second session, it was less writing, less reading. It was more active work and more thinking..."*
>
> *"...Me too..."*
>
> *"...And maybe that it was a bit difficult to keep up in the first session, everything went really fast. It was a lot to do in a short time, in one task you may be able to write one or two sentences, and then you have to move on to the next question. While in the second session we had more time on only one task, so it was a bit more fun to just focus on one thing the whole session..."*

On the same question, another student also expressed something similar;

> *"...In the second session I felt like we got to do more. The first session was reading those papers and writing. Now we got to use some of it..."*

As displayed in the above quotes, the design thinking approach was mentioned across groups and questions. The research task during the discover step was particularly enjoyed by students, as it provided exciting context and opportunities to express thoughts and opinions. Reflecting on the sessions, students found the research task helpful in generating ideas and gaining a better understanding of the topic. The discover and define steps were seen as valuable for the prototyping phase, with students exploring various solutions and improvements. While some students favored the first session for planning and design, others found the second session more engaging due to increased activity and focus on prototyping. However, time limitations and a preference for more active work were mentioned as dislikes by some students, who felt they had insufficient time for the discover and define steps in the first session.

5.1.3 Fun Aspects of the Study

Another theme that emerged from the questions asked in the interviews was "Fun". Several students had different opinions on what they found fun. While some students highlighted specific elements, one group reported a general enjoyment of the whole procedure when asked about what they liked about the procedure;

> *"...Everything we did was quite fun..."*
>
> *"...Especially the collaboration, trying to figure out how we could improve the robot was interesting. Even when you are two or three people working together, its very fun to cooperate in a project like this..."*

On the same question, another group expressed enjoyment of elements included in the prototyping step;

> *"...I think it was pretty fun to program and try to figure out different ways to solve things..."*
>
> *"...I liked building a new robot the most. We mostly used the standard one for trying out different functions and stuff like that, but we had some fun with building a new one..."*

When asked about what they liked the most about the platform, the first group also highlighted programming, and elaborated further on elements of enjoyment;

> *"...Everything was fun! Programming the robot, seeing what different parts of the program does. That the building was on fire, and that we might be able to use this in the future..."*
>
> *"...The fact that something digital can be used out in the real world. It was fun to build something that's based on this, and then put it out to the test in the burning building..."*
>
> *"...Yeah, and that's what's so fun about programming, to find errors in the program, and then make them better..."*

Another student expressed similar opinions when asked the same question;

> *"...It was fun when you were able to make a change, and then you could see the change in the simulator. When you wrote a bit of code, and then what you coded happened in the simulator. It was a lot of fun when it worked, and then you get a feeling of achievement. That was fun..."*

Although the general consensus was that tasks had several fun elements, one group also expressed some limitations to the extent on which the platform should be used;

"...I think that if you were to use this platform for many hours, it could become a bit boring. You would get tired of it. So it was a good thing that we didn't use it for too many classes, but three or four classes would probably also work well..."

Fun elements of the sessions emerged as an important theme from the interviews, with students expressing different aspects that they found enjoyable. While some students found the entire procedure fun, others highlighted specific elements. Collaborating and working together to improve the robot was seen as interesting and enjoyable. Programming and figuring out different solutions were mentioned as fun aspects, along with the excitement of building a new robot. The interactive nature of the platform, where changes in the code were reflected in the simulator, provided a sense of achievement and enjoyment. However, one group mentioned that using the platform for extended periods could become boring, suggesting that it was best suited for a limited number of sessions.

5.1.4 Learning Outcomes

To get an impression of the learning outcome throughout the procedure, the students were asked about what they had learned. This question uncovered different perceptions of what they had learned. One group of students focused mostly on what they had learned about robots;

"...Yes, we learned that robots like this can sort of do a lot of different things. We only focused on fire rescue though, so then we learned about how robots can be helpful in such cases..."

"Yeah, I hadn't thought about that before, that robots could be used in fire rescue, but I think its cool that it is being explored and stuff like that..."

One student focused on interaction with the platform;

"...I would say I learned how to interact with the platform a bit better, that's what I learned. And then I got some more repetition in how to code, how to program..."

One group also expressed how the platform can promote learning while talking about the solutions they tried to implement;

"...If you get enough time and knowledge to actually use the program, you can get it to work very well..."

"Yes, and the process helps with reflecting on the platform as well: okay, what can I do better, what was good, which changes can I make to make the robot easier to use, right..."

"...I think that its a system which is really instructive..."

When asked if they believe the platform can be useful for educational purposes, another group also mentioned programming;

"...Yes, if you want to learn about programming, then this platform will be helpful to use. For modelling as well actually, you can use the platform for both..."

In summary, the interviews revealed diverse perspectives in regards to learning. Some students focused on the knowledge gained about robots and their potential in fire rescue situations. Others highlighted their improved interaction with the platform and increased familiarity with coding and programming concepts. The value of the platform in promoting learning was emphasized by a group of students who discussed the process of reflection and making improvements. They found the platform instructive and believed it could be useful for educational purposes, particularly for learning programming and modeling. The platform was generally considered useful for learning purposes by most of the students.

5.1.5 Interview with the Teacher

In addition to the interviews with the participants, we also interviewed the teacher. Through helping with tailoring the user testing specifically for the students of his class, the teacher had valuable insights and opinions that we wanted to capture. Therefore, an additional follow-up interview was conducted with the teacher one day after the second session.

Overall, this interview sought to uncover if the process that was followed in the two sessions differed from the regular classes, and to which extent these differences manifested in student engagement, focus, classroom dynamics and other relevant aspects.

Contrast to Regular Teaching Methods

Usually, the teaching method revolved around the teacher presenting the curricula, followed by him handing out tasks that were specific and related to the curriculum he had presented. When he educated the class on HTML, for example, some of the tasks included "What does the *header*-tag do?", and "What is the difference between *id* and *class*?". This procedural teaching method differs from the inherently open and creative teaching method that follows from the introduction of design thinking. He had a good impression of the students' work-rate during both sessions:

> *"...It seemed like the students were given very clear instructions, so they could work well on their own. They got good answers when they had questions. I could see that they were satisfied, and that doesn't happen every day. They didn't think it was boring, so it went well..."*

Verdict on Engagement and Interest

While the teacher did not have any suggestions for improvement, he could highlight several positive outcomes in terms of engagement and interest:

> *"...In general, I saw that many of the students were interested in the programming and robotics. It's very futuristic with robotics, which is nice. I also saw that since the instructions were clear, they always had a goal to work towards, and knew what to work on..."*

In summary, the teacher highlighted that the teaching methodology in the two sessions differed from the regular classes. Moreover, he observed that the procedure incited positive outcomes in terms of engagement and interest.

5.2 Artefacts

In the beginning of the first session, the students got handed a pen, paper, and several informational documents related to robots and fire rescue, as explained in section 4.4.2. After the completion of the user testing, these papers were scanned, and the notes taken were analyzed. This section will elaborate on the differences between the notes taken by each group. In addition, photographs were taken of the proposed block-code solution for each group after the second session. These are important, as they help highlight how close the groups came to a working solution. Altogether, these artefacts shine light on valuable metrics that add to the findings of the study.

5.2.1 Notes

There were significant differences in amount of notes taken among the six groups during the first session. There were also significant differences in how many of the given questions the notes pertained to and to what extent the notes were relevant to the topic at hand. Of the six groups participating in the first session, four wrote down suggestions on how to improve the robot, as requested during the define step. However, only one of these groups clearly defined specific proposals they wanted to prioritize during the prototyping.

From a thematic analysis of the notes taken by all six groups, there were four prominent themes:

- Planning.
- Dangers.
- Equipment.
- Functionality.

The analysis of the notes revealed both similarities and differences in the themes identified, as well as variations in the extensiveness of notes taken. While most groups touched on all the prominent themes, the extent to which the notes pertained to the different themes significantly fluctuated. Group 1 provided a more comprehensive and technical analysis of the equipment of the robot, while only making a few notes regarding the remaining three themes. In contrast, group 2 focused more on the process of using the robot for rescue and fire extinguishing, and the dangers associated with it. Functionality was the most prominent theme for this group. They were also the group with the most extensive notes. Functionality was the most prominent theme for group 3 as well. Group 4 emphasized dangers and equipment. Groups 5 and 6 had the least comprehensive notes, with group 5 making a couple notes regarding each theme and group 6 only barely touching on planning, dangers and functionality, with no notes related to equipment. These findings clearly document significant differences in the extensiveness of notes taken and indicate differences in primary focus of the notes taken between groups.

5.2.2 Informational documents

The highlighting done in the informational documents showed similar differences. Only three of the six groups did any relevant highlighting during the session. All of these three groups highlighted text throughout most of the informational documents they were given, indicating that most of the information has been processed. For the remaining three groups, no clear indication was made of what portion of the documents were read.

The thematic analysis of the highlighted phrases from these three groups of students revealed four main themes:

- Hazards and risks.
- Risk management and control.
- Use of technology and equipment.
- Specialized skills and tactics.

Across the three groups of students, the focus on these themes differed. The fist group highlighted several phrases within each of the four themes, but with a significant share of their highlighted phrases pertaining to hazards and risks. The second group highlighted a few phrases regarding use of technology and equipment and specialized skills and tactics, but had most of their phrases evenly distributed between hazards and risks and risk management and control. The first and second group highlighted approximately the same amount of phrases. However, the third group highlighted significantly fewer phrases. They did not highlight any phrases pertaining to specialized skills and tactics, and had a slightly higher amount of phrases pertaining to use of technology and equipment.

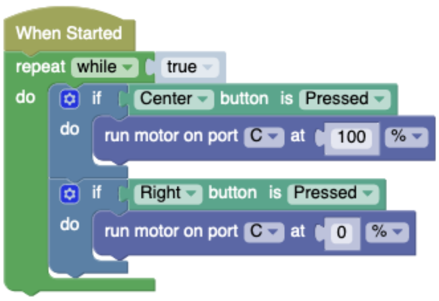
5.2.3 Block-code

As explained in section 4.5.2, we devised a scoring system for the final block-code. Table 7 shows the score we awarded the groups, which is based on how many block-code changes would have to be made to the code in order for it to work as intended. A low score indicates high performance.

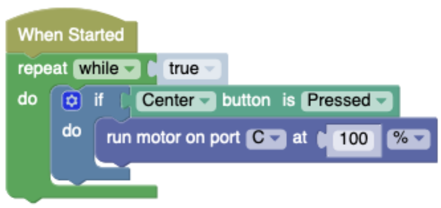
Table 7: Block-code scores.

Group	Final Intention	Score
1	Retrieve/save items from building using human control and motor C	4.0 (1.0)
2	Retrieve/save items from building using color sensor and motor C	5.5
3	Retrieve/save items from building using color sensor and motor C	6.0
5	Retrieve/save items from building using movement and motor C	6.5

All of the groups worked on several different ideas during the second session, but as their final attempt, every group attempted to retrieve the objects in the burning building in some way, which probably is the most straightforward solution to the problem. The importance of having a ill-defined problem that could be solved in many ways was underlined in section 4.4.2. This proposed solution would indeed save the objects form the fire, thereby solving the problem. Their approaches varied, with group 1 being closest to a working solution with an official score of four (4.0), and an unofficial score of one (1.0). Interestingly, they discovered an unknown way of solving the problem, unbeknownst to us before they demonstrated it. The number in parentheses in Table 7 denote this solution - as they only lacked one while-loop for this to work. When opting for this solution, one would normally have to program both the conditional retrieval and release of the objects. However, group 1 discovered that they could stop and resume the simulation, which would trigger a release of the objects, meaning that they only had to program the retrieval, a surprisingly elegant solution to the problem. As briefly mentioned and shown in Figure 11 in section 4.5.2, there was a proposed solution for the retrieval of the objects. Figure 13 shows the two relevant solutions for the attempts made by the participants. Figure 13a shows the intended solution for the problem, while Figure 13b is the "hacky" solution inspired by group 1.



(a) Proposed solution



(b) Unofficial and "hacky" solution

Figure 13: The two relevant solutions for the groups' proposals.

5.3 Log Data

Log data was collected in both sessions, but given the nature of the two sessions, the log data from the second session is more insightful. There are several reasons for only focusing on the log data from the second session. First, all of the work in the second session is measurable by log data, as they solely interacted with the platform. In the first session, on the other hand, the participants took notes, underlined research material, and spent less time interacting with the platform. Secondly, the data about how they proceeded to prototype in the develop-step is much more rich than their interaction with the modal in the first session. Third, more time was spent interacting with the platform in the second session. As a result, all of the log data in this section pertains to the second session. Figure 14 shows the distribution of triggers across the four groups that took part in the second session. As one can see, group 1 had substantially more triggers than the remaining three groups, who had comparatively similar numbers. Figure 15 depicts a more granular distribution on the four types of triggers that contribute most towards the evident adherence to the *Develop*-step of the design thinking approach.

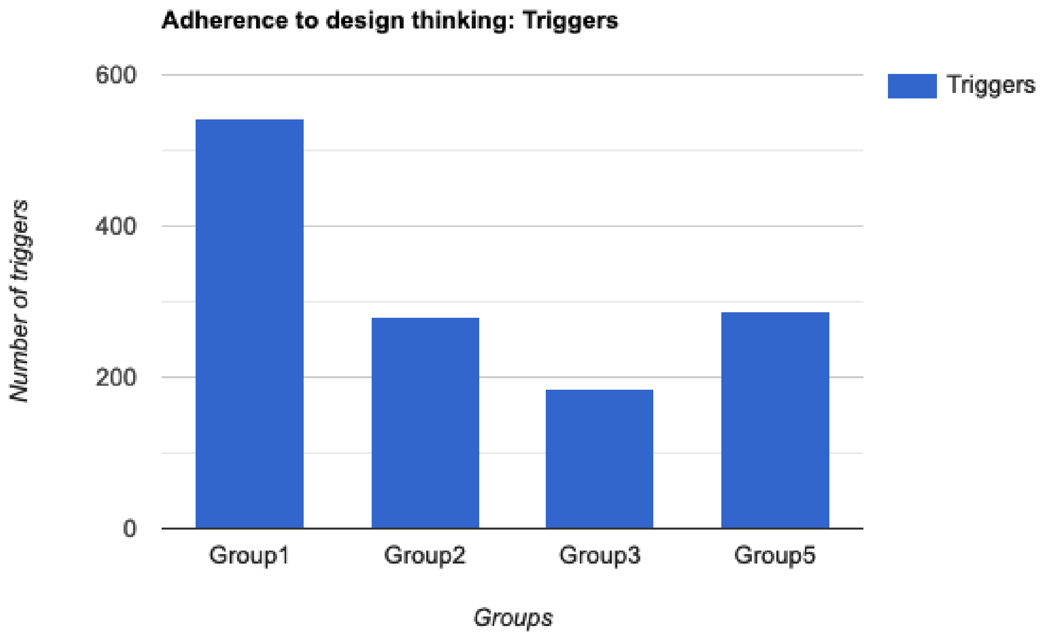


Figure 14: Number of triggers per group.

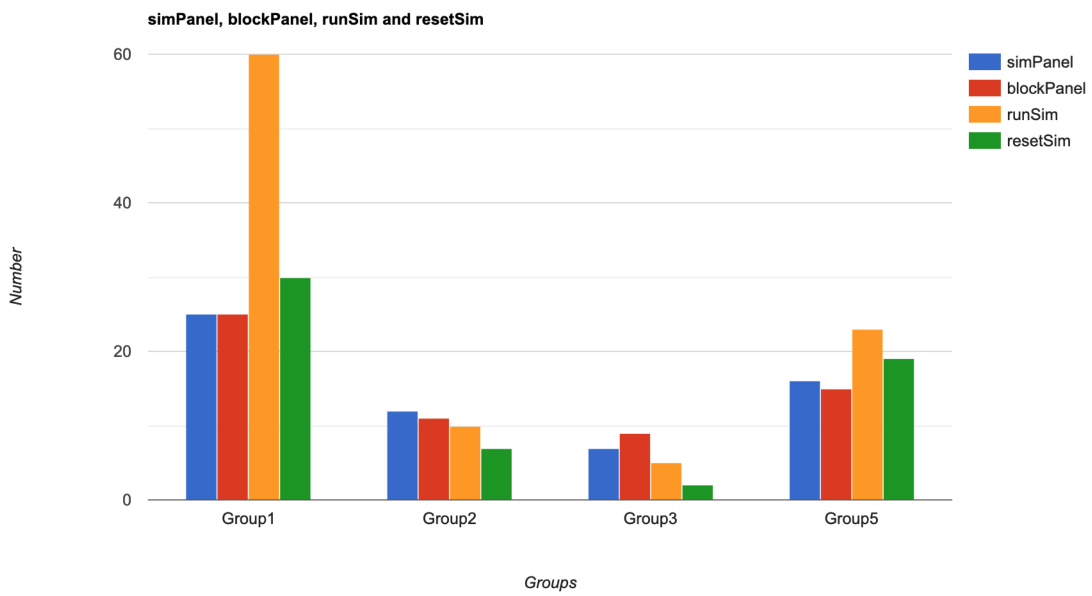


Figure 15: Combined markers of adherence to design thinking.

Table 8 presents the variables pertaining to the develop-step of the design thinking approach. In other words, these metrics describe how the groups tested their ideas in the platform. In addition, it includes means and standard deviations of the variables.

Table 8: Log data from session 2.

Trigger	Group 1	Group 2	Group 3	Group 5	Mean	Std.Dev
numTriggers	543	281	186	288	324.5	152.915
simPanelCount	25	12	7	16	15	7.616
blocksPanelCount	25	11	9	15	15	7.118
pythonPanelCount	4	1	4	0	2.25	2.062
arrowCount	205	78	29	77	101	75.385
runSim	61	10	5	23	21	25.330
resetSim	30	7	2	19	14.5	12.557
toggleHubButtonCount	0	6	5	8	4.75	3.403
hubButtonsCount	0	29	5	4	9.5	13.178
aswdKeys	22	32	4	4	15.5	13.892
joystickToggledCount	3	1	3	7	3.5	2.517
joystickResetCount	102	76	91	47	79	23.847
toggleSensorPanel	0	1	0	1	0.5	0.577
toggleCameraSelector	0	2	0	0	0.5	1
backspaceCount	14	0	4	5	5.75	5.909
spaceCount	19	1	3	0	5.75	8.029

At first glance, we can observe that group 1 has the highest values for nearly all variables. A notable exception is hubButtonsCount, which is highest in group 2.

To perform pairwise t-tests with a Bonferroni correction, we need to compare each group to every other group. Since there are four groups, we will need to perform six t-tests (group 1 vs. group 2, group 1 vs. group 3, group 1 vs. group 5, group 2 vs. group 3, group 2 vs. group 5, and group 3 vs. group 5).

To apply a Bonferroni correction, we will divide the usual significance level (0.05) by the number of tests (6), giving us a new significance level of 0.00833 (0.05/6). If the p-value for a t-test is less than this adjusted significance level, we will reject the null hypothesis and conclude that there is a significant difference between the two groups.

Table 9 shows the results of the pairwise t-tests with a Bonferroni correction.

Table 9: T-test values with a Bonferroni correction.

Test	t-value	df	p-value
Group 1 vs. Group 2	7.899	26	$\mathbf{p < 0.0001}$
Group 1 vs. Group 3	11.257	26	$\mathbf{p < 0.0001}$
Group 1 vs. Group 5	4.384	26	$\mathbf{p = 0.0002}$
Group 2 vs. Group 3	-1.698	26	$p = 0.1023$
Group 2 vs. Group 5	-1.645	26	$p = 0.1142$
Group 3 vs. Group 5	-1.029	26	$p = 0.3126$

Based on these results, we can conclude that group 1 is significantly different from Groups 2, 3, and 5, and that there is no significant difference between Groups 2 and 3, Groups 2 and 5, or Groups 3 and 5.

While the t-test tell us that the groups are different, it does not provide direct answers to what the most significant differences are. To gain further insight into what exactly accounts for the majority of the variance, one can perform a Principal Component Analysis (PCA). PCA was chosen for this analysis to reduce the high-dimensional nature of the data set and to identify the most important variables that contribute to the variance in the data. The PCA results show that the first two principal components (PCs) explain 80.1% of the variance in the data. The first PC explains 58.6% of the variance, and the second PC explains 22.4% of the variance. Using the format shown in Table 10, the explained variance ratio is 0.58559892 and 0.22405583 for PC1 and PC2, respectively.

Table 10: PCA values.

Group	PC 1	PC 2
Group 1	5.23381035	-0.50494354
Group 2	-2.52477816	-2.54151579
Group 3	-1.49878577	0.30158208
Group 5	-1.21024642	2.74487725

The first principal component pertains to the variables that contribute the most to the variance in the data are numTriggers, arrowCount, runSim, and resetSim. These variables are related to the user's interactions with the simulation, such as triggering events and controlling the simulation. The second principal component is related to the user's use of the platform's interface and input methods. The variables that contribute most to the second source of variance are aswdKeys, joystickResetCount, blocksPanelCount, and simPanelCount.

The scatter plot of the data in the space of the first two principal components in Figure 16 shows that there is a clear separation between group 1 and the other three groups. Group 1 has higher values on all of the variables that load heavily on the first principal component, which suggests that they are more engaged with the simulation than the other groups. Groups 2, 3, and 5 have similar values on the first principal component, but group 2 has a lower value on the second principal component, which suggests that they use the platform's interface and input methods differently than the other groups.

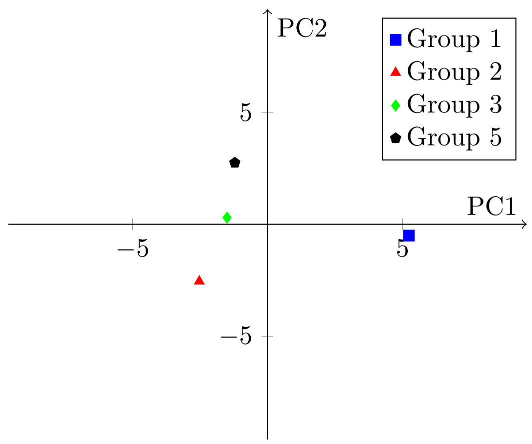


Figure 16: Scatter plot of the PCA values.

Overall, the PCA results suggest that there are two main dimensions that explain the variance in the data, one related to the user's interactions with the simulation and the other related to the user's use of the platform's interface and input methods. The results also suggest that group 1 is more engaged with the simulation than the other groups, and that group 2 has a unique use of the platform's interface and input methods compared to the other groups.

5.4 Questionnaires

A total of fifteen participants answered the pretest questionnaire, while eight participants answered the posttest questionnaire. Two of the participants were females in both tests, the remainder were male.

5.4.1 Pretest

Table 11 shows the descriptive statistics for the values measured in the pretest questionnaire.

Table 11: Statistics of values from the pretest questionaire

	Mean	**Median**	**Mode**	**Range**	**Std.Dev.**
experienceProg	3.73	4	4	5	1.35
experienceRob	3	3	2	4	1.33
experienceDT	3.13	3	4	6	1.6
interestRob	4.47	5	5	5	1.22
interestDT	3.67	4	3	5	1.16
motivation	5.07	5	4	4	1.36

Table 12: Pearson correlation coefficients between variables

	expProg	expRob	expDT	interestRob	interestDT	motivation
expProg	1.000	0.6505	0.4122	0.0057	0.1373	-0.0239
expRob	0.6505	1.000	0.2771	-0.0031	0.0619	-0.2307
expDT	0.4122	0.2771	1.000	-0.189	-0.3496	-0.0471
interestRob	0.0057	-0.0031	-0.189	1.000	0.6131	0.3264
interestDT	0.1373	0.0619	-0.3496	0.6131	1.000	0.607
motivation	-0.0239	-0.2307	-0.0471	0.3264	0.607	1.000

From Table 12, one can observe that there is a moderate positive correlation between expProg and expRob (0.6505), interestRob and interestDT (0.6131) and interestDT and motivation (0.607). Given the limited sample size, the remaining values cannot be considered significant.

5.4.2 Posttest

Table 13: Statistics of values from the posttest questionaire

	Mean	**Median**	**Mode**	**Std. Dev.**
Intuitive	6.625	7	7	0.7497
Exciting	5.625	5.5	5	1.0479
Fun	5.125	5	6	0.9574
Learning	5.375	5.5	5	1.5632
Interest in repeat	5.875	6	6	0.8367

Based on the information provided in Table 13, it seems that the participants found the platform to be generally intuitive, exciting, and fun, with mean scores ranging from 5.125 to 6.625 out of 7. The participants also showed a high level of interest in repeating the activity, with a mean score of 5.875 out of 7. On the other hand, the learning aspect of the platform received a lower mean score of 5.375 out of 7.

In addition to the quantitative questions, four qualitative questions were included in the posttest questionnaire, as presented in Table 5. From the thematic analysis on these four questions, we can derive the insights described below.

The participants were asked to highlight the easiest part of the sessions, and both participants in each group gave the same answer. The following four answers were given:

- Robot construction
- Driving with arrow keys
- First session (discover and define steps)
- Figuring out what improvements the robot needed

On the question of what the students found the most difficult, all but one student gave answers related to coding of the robot. Two of the students also mentioned time as a limiting factor.

When asked to give a description of what design thinking is, several relevant concepts were mentioned. Creativity, designing, and thinking of new ways were all mentioned by two to three students. The student providing the most complete description described it as "Thinking out an idea, then working with it an making a prototype, so you get a finished product that works in the intended way." This was by far the most correct answer, and whilst most student mentioned something that can be related to design thinking, their descriptions were generally way off.

When asked to provide a description of what virtual robotics is, the themes mentioned were mostly relevant. All but one student mentioned coding or programming, and most of the students related this to robots. Three of eight students also touched on the theme of digital or virtual representation compared to physical robots.

5.5 Connections Across Groups and Data-types

Connections across the different groups may not clearly emerge based on the previous results-sections, as it would not make sense to include group-wise views for all of the results. Therefore, we explicitly point out connections as they pertain to the results in this section. We make distinctions across groups because there is evidence to support the fact that design thinking helped the groups in different ways. Hence, examining what made the groups different, and how this influenced how design thinking helped them, is of valuable insight. These connections are further discussed in section 6.

There was a clear connection between the the general notes taken and the interaction with the available informational documents in the first session. All three groups that made highlights in the informational documents also made a significant amount of notes and wrote down suggestions of improvement. Moreover, the notes taken by the three remaining groups were on average far less comprehensive.

When asked to express motivation to complete the planned sessions in the pretest questionnaire, three students answered 7 and one answered 6 of a maximum score of 7. These four students were all participants of groups 1 and 2 (group 1 also had one student only attending the first session, who gave a motivation score of 5). These two groups also took significantly more notes and highlighted more than the other groups. Furthermore, these two groups expressed more enjoyment of the first session during the interviews than the rest.

A closer comparison of these values between the two groups does, however, show some differences. Group 2 scored the highest of all groups on motivation (7 + 7), did the most extensive note taking and highlighting and were the only group to define specific improvements they wanted to implement, which was the final task of the first session. Group 2 also stated clearly that they both preferred the first session, and provided the most accurate explanations of design thinking and virtual robotics in the post test questionnaire. Interestingly, they answered the lowest perceived learning outcome of all students. Both students of group 2 answered 3 on this question, while all other students answered 5 or higher. All other students also expressed clear enjoyment of the second session. Group 2 also expressed greater difficulties with the prototyping task during the interview than the other groups.

6 Discussion

This study has investigated how students perceive learning in an educational virtual robotics environment with a design thinking approach. The results presented in section 5 will be discussed in relation to the research question in this section.

6.1 Impact of Motivation and Attitude Towards Tasks

In the pretest questionnaire given before the first session, the students gave an estimate of how motivated they were to perform the planned work of the sessions. The students generally expressed motivation in the upper end of the scale, with a mean value of 5.07 of a maximum of 7, while a standard deviation of 1.36 indicate that students reported different degrees of motivation. When looking closer at the numbers, a few students stand out as the most motivated, with four students reporting a motivation of 6 or 7. Interestingly, these students were all part of the two groups that achieved the best performances in the first session with relation to note taking and highlighting of relevant information, judging by the amount and quality of their work.

During the interviews, the same students that completed the tasks given in the first session with the highest quality and extensiveness also expressed higher enjoyment of the tasks completed in the first session. On the other hand, the remaining students, who performed significantly worse in the first session, all expressed less enjoyment than the aforementioned highly motivated students, primarily caused by a dislike of tasks that focus on reading and writing. These connections provide a clear indication that motivation and attitude towards the tasks greatly impacted the performance in the *discover* and *define* steps of design thinking during the first session.

Similar tendencies can be seen for the second session, although they did not have the same impact. All groups except one also expressed high enjoyment of the second session. The only group that expressed any limitation to their perceived enjoyment was group 2. They did not directly state any dislike for the second session, but clearly expressed greater enjoyment of the first session. When asked what they found most challenging, they instantly referred to the coding related to the prototyping. Several students mentioned that they found the prototyping task of the second session challenging to complete in the limited time, but the students of group 2 expressed more significant difficulties than the other groups. Despite these perceived difficulties, group 2 did not perform any worse than the other groups, as shown by the scores in Table 7. While students preferred different steps of the design thinking approach, all students expressed engagement during the activity, supporting the findings of Loundon that student engagement can be enhanced by integrating design disciplines into STEM curricula [30].

While the expressed rate of difficulty varied between groups, all groups indicated that they were engaged in the task during the second session. The two groups that reported the lowest enjoyment of the first session, and also answered the lowest estimated motivation in the pretest questionnaire, both expressed in the interviews that their motivation was higher during the second session. Taking into consideration that the students expressing the least enjoyment of the prototyping did not perform any worse than the remaining groups, and thus, attitude towards the task did not impact performance in the prototyping, there are clear indicators pointing to motivation as a significant influencing factor for performance. There seems to be indications, albeit less significant, that attitude towards tasks can amplify the effects of motivation, but there is not sufficient evidence of this to draw any conclusions.

6.2 Learning Outcome and Enjoyment

Both ”fun” and ”learning” protruded as significant themes from the interviews, and students mentioned different elements of the sessions that related to both concepts. In general, the statements given by the students regarding these two themes do not specify the degree of how fun and rich in learning the sessions were, but some expressions, such as ”...quite fun...”, ...everything was fun...” and ”...really instructive...” imply that the sessions were perceived to provide quite high levels of fun and learning. These findings were supported by the answers given in the post test questionnaire (Perceived fun M=5.125, Std.Dev=0.9574 and Perceived learning M=5.125, Std.Dev=1.5632). These results support the claims made by Adams & Nash, as well as by Brown, that the design thinking approach can significantly enhance the ability to learn STEM-concepts like physics [28, 29].

While both these mean scores are moderately high, there is a significantly higher standard deviation for perceived learning.

One benefit of the low number of participants, which generally limits the significance of the findings in the questionnaire, is that it allows for more detailed exploration of the values provided by each student. As mentioned in section 5.5, both members of group 2 answered a perceived learning outcome of 3. Given that the remaining values provided for the question of perceived learning outcome were 5 or higher, these two answers clearly contribute greatly to both reducing the mean and increasing the standard deviation. The timing of the question should be taken into consideration in this case, as the posttest questionnaire was answered by the students directly following the second session. Comparisons between perceived learning, provided in the posttest questionnaire, and the enjoyment and attitude towards the tasks of the second session, expressed during the interviews, convey a comprehensive connection. All students that expressed significant enjoyment and positive attitude towards tasks in the second session reported a perceived learning outcome of 5 of higher, while the two students of group 2, which did not express the same enjoyment and positive attitude towards the tasks reported a perceived learning outcome of 3. These values strongly suggest that perceived learning from the sessions were mostly based on the experiences of the second session. As illustrated in section 4.4, the inclusion of virtual robotics was quite limited in the first session, while the second session focused primarily on interaction with the virtual robotics platform. Based on the documented findings, perceived learning seems to be strongly related to virtual robotics, and not design thinking. What this discovery indicates for the potential of combining design thinking and virtual robotics is uncertain, but it does align with the opinion of Hsiao et al. that robot-based practises can yield better results when compared to ”normal” lectures [40].

The findings of the study visibly state moderate to high perceived learning outcome for most of the students. However, certain factors should be taken into account when considering how these results translate to achieved learning outcome from the sessions. Due to the limited number of participants in the study, there was no possible way to complete the study with a control group. Consequently, the performance of the students can not be compared to performance of a group of students that did not combine design thinking and virtual robotics to solve the same challenge. The finding for perceived learning outcome from the posttest questionnaire and interviews still still seems meaningful, as the results are consistent across both data types, but cannot be confirmed by comparison to a control group or any established expectation of performance. Additionally, performance and answers given by group 2 generate incertitude of the accuracy of the estimated perceived learning. The group achieved a score on the final solution that precisely equals the average of the groups, and displayed greater understanding of the concepts of design thinking and virtual robotics in the posttest questionnaire than the remaining groups. The contradiction between these factors and their perception of achieved learning outcome somewhat limits the validity of the results.

6.3 Evaluation of Platform and Tasks

A successful implementation of an educational activity intended to combine design thinking and virtual robotics is largely dependent on a virtual robotics platform that is intuitive and easy to use, as well as design thinking related tasks that are clearly expressed and effectively guide the students through the activity. Hartnett identify assessment pressure, lack of relevance, and unclear or complicated guidelines as pitfalls that would negatively impact learning if not avoided in online contexts [47]. Thus, quality in both platform and tasks was important to unveil any potential synergistic effects between design thinking and virtual robotics.

The virtual robotics platform was overall well received by the students. During the interviews students expressed that the design and functionality was *"quite intuitive"*, and the simulated world was simple and easy to understand. However, some students found the steering of the robot difficult to master, and provided suggestions of improvement to the implementation on the controls. On the other hand, one student also stated that "*...everything was rather simple to understand. I don't really think there is much to improve...*". Despite the dissatisfaction with the controls expressed by some students, all students generally found the platform to be largely useful. One student pointed out how broad skill activation the platform was able to achieve, mentioning programming, collaboration and communication, design and thought processes, while another student stated that they got to utilize skills they rarely use. Both of these statements support the claim made by Komis et al. that scenario based use of educational robotics may indirectly address extracurricular concepts in an interdisciplinary perspective [12].

The tasks given to the students seems to have worked well in combination with how the platform was used. In the post-test questionnaire, the students expressed that they found the tasks given during the activity to be extremely clear, with a mean value of 6.625 out of 7. Furthermore, they expressed significant interest in participating in similar activities in the future, supporting statements made by Melchior et al. and Jung & Won claiming that exposure to robotics in an educational setting can facilitate increased engagement among students in complex concepts [38, 39].

6.4 Using Design Thinking to Accommodate Differences

The fact that people are different is one of few certainties in life, and this is reflected even in the small sample size of this study. Of the four groups that participated in the second session, a clear pattern emerged from the log data, and the discrepancies between the groups becomes evident when looking at Table 8 and Figure 16. The scatter plot in Figure 16 highlights the differences between the groups in the two principal components, which in turn accounts for 81.0% of the total variance combined. Groups 1 and 2 are most "unique", while Groups 3 and 5 are closest to one another (with t-tests value of -1.029 between group 3 and group 5).

Interestingly, the differences between the groups highlight a potential benefit of using design thinking in K-12 education. Group 1 and group 2 are examples of this. Indeed, group 1 provided a more comprehensive and technical analysis of the equipment and functionality of the robot, instead of focusing on other themes while taking notes during the first session. In comparison, the other groups had a less "technical" approach. Group 1 also claimed in the interviews that they "were ready to start prototyping as soon as we finished the design". This willingness to prematurely proceed to the *development*-step highlights the importance of following the design thinking approach in order to avoid committing to one idea before doing adequate foundational work. Delaying the start of development induced increased adherence to the previous two steps, which is likely to improve the quality of their final solution. This finding is in line with the claim by Vossen et al.: "*some students prefer to skip research and start building their design right away*" [58]. The emerging differences between the groups are further backed by the principal component analysis, in which the values of the first principal component insinuate that group 1 generated vastly different data than the rest, thus being a main contributor to the variance.

Group 2, on the other hand, preferred the first session. Their preferences seems to mostly favour the *discover*-step of the double diamond approach;

> *"...It was very exciting to read about the robots in context of fire rescue. I also enjoyed writing down our thoughts and opinions, and to answer those questions we were given in the modal..."*

This is also reflected in the sheer amount of notes they generated during the first session compared to the rest.

Group 1 explicitly stated that they would have preferred to start coding earlier. Group 2 stated the opposite, reporting that "the first session went by really fast", and that they found the writing and thinking most fun. Still, the design thinking methodology required that both groups completed the stages they found most strenuous. Exertion, likely being a prerequisite for learning, is desired in these settings so long as it does not invoke sufficient negative emotions to inhibit engagement. Moreover, the fact that some students had different preferences than others could make for conducive learning environments when these students with different preferences are asked to collaborate with one another. This naturally assumes that their ability to cooperate roughly remains equal or improves. In this study, it is evident that the groups derived benefit from complementary parts of the design thinking approach.

6.5 Learning that Exceeds Curriculum

Problem-solving with virtual robotics and design thinking can be an inherently creative, open-ended and challenging endeavour, which invariably rewards students that are able to acquire or use other useful skills. During the interviews, it became evident that this acquisition and usage of new skills had occurred during the two sessions. Collaboration, one of the 21st century skills, is an example of this. Despite not being a skill that we consciously taught the students, it protruded as an aspect of the empirical study that the participants enjoyed and seemed to derive benefit from. As previously listed in section 5.1, a participant mentioned collaboration as a "fun" aspect;

> *"...Especially the collaboration, trying to figure out how we could improve the robot was interesting. Even when you are two or three people working together, it is very fun to cooperate in a project like this"*

This is in accord with the related work cited in section 2.3.1, where it was stated that design thinking can represent a generative and positive educational experience, which not only contributes to the knowledge development of individual students but can also result in creative social contributions.

During construction of the Activity Plan in Appendix C, some possible drawbacks of collaboration were discussed with the teacher. As collaboration sometimes can lead students to socialize and thereby do other things than focus at the task at hand, we had to consider if allowing collaboration would have any adverse effects on focus and engagement. In a literature review on collaboration in education, Lawson concluded that collaboration may be a defining feature of competent and optimal practice. However, despite its immense potential, a significant problem emerges from the existence of "*imprecise, incoherent and competing conceptions of collaboration*" [61]. In retrospect, this was wholly unproblematic as most of the participants thought that tasks were clear, the speed was really high, and the sessions were fun. Even in the first session, where the participants spent most of the time reading, thinking, discussing and writing, they reported high speed and enjoyment;

> *"...In the first session, everything went really fast. It was a lot to do in a short time.."*
> *"...I think the first session was the most fun, because then we were planning what to do. We spent a lot of time trying to figure out how to make the robot better. I really enjoyed the design phase..."*

By giving this sense of urgency and direction, design thinking may aid in inciting productive collaboration in K-12 education. Given the participants' proclivity to talk highly of collaboration in the two sessions, we can also assume that it was a positive driver for engagement and learning.

Learning through educational robotics also has a tendency to exceed the curriculum, which also seems to be the case here. Indeed, while the task presented to the participants solely pertained to fire rescue, groups made general remarks about other uses for robots;

> *"...We learned that robots like this can sort of do a lot of different things. We only focused on fire rescue though, so then we learned about how robots can be helpful in such cases..."*

Adding to this effect, the application of design thinking can be a helpful tool to aid a holistic approach to acquisition and application of knowledge, as mentioned in section 2.3.1. One of the participants came to the following realization;

> *"...I noticed that I got to utilize skills that I don't use often. I think that's a very nice way to create engagement among the students, because you get to do more than when you are just sitting down and writing. You will also get a better understanding of how everything is connected..."*

The last part of the above quote is especially interesting, as it could indicate acquisition of the highly desirable high-road transfer that was introduced in section 2.3.3. A holistic understanding of "how things are connected" does indeed seem indicative of knowledge that is at least partly decontextualized, one of the hallmarks of successful abstraction.

Some other skills that were mentioned in the interviews include programming, collaboration, communicating with friends, design, thought processes, logical thinking, reflection and cooperation. Except for programming, none of these skills were mentioned to the participants. Given that the participants mentioned these skills, many of which are included in our definition of 21st century skills, the combination of virtual robotics and design thinking does indeed seem to invoke learning of the 21st century skills. The alignment with the philosophy of constructionism could be one of the explaining factors of why the learning seems to have exceeded the "curriculum". As mentioned in section 2.3.2, educational robotics provide great conditions for adherence to constructionism [43].

6.6 Limitations

We would be remiss if we refrained from acknowledging that the findings in this study is greatly impaired by the small sample size. Despite our continued efforts to recruit additional participants, no help was received from other schools. There were only 16 students in the class that graciously agreed to cooperate, of which several were absent due to a field trip during the second session. This left only 15 and eight participants for the first and second session, respectively. The absence in the second session was particularly detrimental, as it considerably reduced the amount of data gathered from the interviews, log data and block-code results, as well as the post-test questionnaire. The low number of participants compelled us to emphasise the collection of qualitative data, as we would be unable to make any conclusions purely based on quantitative data from such a limited sample size. A mixed-method approach with triangulation was followed to mitigate the drawbacks of the small sample size. Whilst the use of triangulation justify the use of the quantitative data to support the findings in the qualitative data, we acknowledge the fact that the results from the quantitative data has substantially limited credibility.

Moreover, we would have preferred to do a more extensive testing than merely two sessions lasting one hour each. The short duration prevented us from devoting the desired time to all of the aspects of the design thinking approach. As a consequence of this, we were forced to leave out the last step of the design thinking approach, the *deliver* step, from the activity plan. Furthermore, we had to impose limiting time restrictions for the three steps that were included. These consequences were emphasized in the interviews and post-test questionnaire, where several students expressed concerns regarding the amount of time provided for the tasks. Preferably, each step of the design thinking process would have been bestowed a separate session lasting at least one hour each. Unfortunately, this was not possible due to an already tight semester plan set for the class, which was finalized several months before the agreement of participation was made. The suggestion of specific technology training prior to user testing, as mentioned in section 2.3.3, was attempted [48]. Sadly, given our restricted time and access to the participants, we were unable to include this preparation. Kucuk and Sisman also demonstrated that more time should be devoted for children to build and explore the complex material, which we were unable to do [62]. Whilst the limited time and number of available sessions were a hindrance for the study, we would like to express our deepest gratitude towards the school, and especially the teacher of the class, for allowing our research to take up two sessions that would otherwise be spent on their pre-planned curriculum.

7 Conclusion

In this study, we investigated how students perceive learning in an educational virtual robotics environment with a design thinking approach. Through an empirical study spanning two one-hour sessions, we used a virtual robotics platform to generate and collect data. An overall high satisfaction can be derived from the participants' reported learning outcome, enjoyment, and evaluation of the platform and tasks. There is also evidence to support that motivation and attitude towards tasks significantly impacted performance.

Based on these findings, we argue that the combination of design thinking and virtual robotics can be beneficial in two salient manners. First, most students have a preference for a specific part of the design thinking process, which is often accompanied by a dislike for the other parts. By enforcing adherence to the design thinking process, the students are required to devote as much effort and time to the endeavours they find strenuous as they to the steps they prefer. Second, this study confirms that the broad learning that seems to occur when students use either educational robotics or design thinking also occurs in the amalgamation of the two. In particular, the combination seems to be adept at invoking learning of the aforementioned 21st century skills.

Given the small sample size, more research is needed on this topic to confirm these findings. Still, this study highlights interesting differences and patterns in the data, which one undoubtedly can derive value from. Regardless, research at a larger scale, including between-group studies, is needed to validate the findings of this study.

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Appendix

A Questionnaires

Brukertesting spørreskjema 1

Obligatoriske felter er merket med stjerne *

Navn *

Kjønn *

- Mann
- Kvinne
- Annet
- Ønsker ikke å oppgi

Hadde du noen erfaring med programmering før aktiviteten? *

Ingen erfaring — Svært mye erfaring

1 2 3 4 5 6 7

Verdi

Hadde du noen erfaring med robotikk før aktiviteten? *

Ingen erfaring — Svært mye erfaring

1 2 3 4 5 6 7

Verdi

Hadde du noen erfaring med Design Thinking før aktiviteten? *

Ingen erfaring — Svært mye erfaring

1 2 3 4 5 6 7

Verdi

Hvor interessert er du i å lære mer om robotikk? *

Svært lite interessert — **Svært interessert**

1 2 3 4 5 6 7

Verdi

Hvor interessert er du i å lære mer om Design Thinking? *

Svært lite interessert — **Svært interessert**

1 2 3 4 5 6 7

Verdi

Hvor motivert er du for å gjennomføre denne aktiviteten? *

Svært lite motivert — **Svært motivert**

1 2 3 4 5 6 7

Verdi

Brukertesting spørreskjema 2

Obligatoriske felter er merket med stjerne *

Navn *

Det var lett å forstå hva vi skulle gjøre i timene *

Helt uenig — Helt enig

1 2 3 4 5 6 7

Verdi

Timene var spennende *

Helt uenig — Helt enig

1 2 3 4 5 6 7

Verdi

Timene var morsomme *

Helt uenig — Helt enig

1 2 3 4 5 6 7

Verdi

Timene var læringsrike *

Helt uenig **Helt enig**

1 2 3 4 5 6 7

Verdi

Jeg kunne tenkt meg å gjøre noe lignende igjen *

Helt uenig **Helt enig**

1 2 3 4 5 6 7

Verdi

Hva synes du var enklest? *

Hva synes du var vanskeligst? *

Forklar hva du tror Design Thinking handler om. *

Forklar hva du tror virtuell robotikk handler om. *

B Interview Guide

Intervjumal

Intervju elever

1. Var det noe dere likte med opplegget?
2. Var det noe dere mislikte med opplegget?
3. Hva likte du mest med verktøyet som ble brukt?
4. Hva likte du minst med verktøyet som ble brukt?
5. Hvilke løsninger prøvde dere å implementere?
6. Følte dere at løsningen dere kom opp med løste ett eller flere av problemene ved brannredning?
7. Hvilke deler av opplegget følte dere ble enklere underveis?
8. Likte du best den første eller andre timen? Forklar hvorfor.
9. Lærte dere noe av de to timene?
10. Har dere noen tips til ting vi kan forbedre eller fikse med verktøyet?
11. Tror dere verktøyet kan brukes til noe nyttig innen utdanning?

Intervju lærer

1. Hvordan pleier dere vanligvis å jobbe i dette faget?
2. Hvordan opplevde du at elevene jobbet med verktøyet under testingen?
3. Hva tror du et verktøy som dette (virtuell robotikk) kan bidra med innen utdanning?
4. Hvilke bruksområder ser du for noe som dette i din egen undervisning?
5. Har du noen tips til ting vi burde forbedre eller fikse med verktøyet?
6. Hva tror du elevene lærte i de to timene vi har hatt?

C Activity Plan

Activity Plan for User Testing a Design Thinking Project with Virtual Robotics

1 Basic Information

Activity Title: Design Thinking learning with focus on Virtual Robotics

Authors: Øyvind Schjerven (Master student), Kristoffer Nyvoll (Master student)

Topic (theme): The potential use of robots in fire rescue

Final Product: A virtual robotics simulator called Gears (https://gears.aposteriori.com.sg) through which the players will learn about Virtual Robotics, Block and Python Programming, Design Thinking and Problem Solving. The target audience of the game would be young adults.

Domains: Programming, Robotics, Critical Thinking

2 Summary

With the technological development of the last decades, new technologies, including robotics, are constantly becoming relevant in new contexts. In this DT project, the students (aged 15-16 yrs old) are tasked with understanding and exploring the capabilities of using robotics in fire rescue situations in an existing virtual robotics environment. The students have to first discover what the environment involves, how it works, and how the block coding and simulation interoperates. Then, they must abstract this knowledge in order to understand what one could accomplish in this environment (create, modify a robot), program a robot, interact with a robot in a simulated space. In order to facilitate sufficient immersion in the environment and attention to detail, we prompt the students to formulate suggestions for improvement of the environment.

3 Focus, Setup and Activity Requirements

3.1 Learning outcomes

Domain related	Be able to understand the connection between the blocks and their accompanying python equivalent (Programming).
	Be able to describe what virtual robotics is, and understand what the robot can do (Robotics).
	Be able to detect errors, areas of improvement and look critically at the environment (Critical Thinking).
Technology related	Be able to navigate around in the environment, click the correct (i.e. appropriate at the current moment) tabs and buttons.
	Be able to comply with instructions and eventual error messages.
Design Thinking & innovation related	Be able to collaborate efficiently with the other teammate.
	Be able to **discover** the capabilities of the environment, along with the limitations and usefulness.
	Be able to **define** how the environment could be improved, in addition to how it currently works.
21st century skills related	Collaboration, computational thinking, critical thinking

3.2 Participants & Context

Students

- Age: 15-16 yrs old
- Prior knowledge: Basic block & Python programming. Cooperation. Used macbooks
- Nationality: 15 Norwegian students
- Language: Norwegian
- Special needs: none

Time

- Activity duration: 2 hours
- Implementation duration: 3 weeks
- Schedule: 1 hour two separate weeks.
- Comment: Additional assignments will be encouraged outside the two sessions, but is not strictly mandatory (cannot be upheld)

Space

- Activity type: Physically, in-person
- Physical space: Classroom setting
- Virtual space: Tailored implementation of Gears platform

- Virtual space: Tailored implementation of Gears platform

3.3 Social Orchestration

Population
- 15 students, 2 organizers, 1 teacher

Grouping & Interactions

Grouping Criteria	Seating (pseudo-random)
Setting	6 groups/pairs, each group/pair has one computer
Roles in the group	No instructions, decided naturally by the group/pair
Organizers' roles	Facilitate, monitor, educate
Teachers role	Facilitate

3.4 Artifacts & Materials

Digital tools
- Tailored implementation of Gears platform

Physical artifacts
- 6 macbooks provided by the school
- Organizers' macbooks to monitor captured data from Gears platform
- Printed documents pertaining to the topic

4 Implementation - Activity Flow

This section describes how the teaching and learning process is expected to evolve through the first three phases of the Design Council's Double Diamond Design Thinking Methodology: Discover, Define and Develop[1]. The described activities should support the objectives stated and make use of the materials, tools and teaching and learning processes mentioned earlier in the activity plan. The engagement with the stages should be iterative and not linear.

4.1 Phase 1: Discover

In the "discover" phase students explore (diverge) and understand the problem of their project. This involves, for example, empathizing with people who are affected by the circumstances of the topic and understanding the needs of the potential users. In this phase they can use the project technology, understand the environment (e.g. to play

1 https://www.designcouncil.org.uk/our-work/skills-learning/tools-frameworks/framework-for-innovation-design-councils-evolved-double-diamond/

around with Gears to figure out how it works) and think critically about their own and others' requirements for the tool.
Duration: 40 minutes

Summary: Students are first given an introduction to the setting/circumstances, and Gears. Then, they are split into groups of 2-3 students and receive their macs with the environment running. There, the students will be given access to a modified version of the Gears platform, where they will play the game “Fire Rescue”. The purpose of this is to give the students insight into how fire rescue is performed, and how virtual robotics works. Gaining a basic understanding of virtual robotics is an important element of this step, as it is necessary in order to gain significant understanding of the underlying topic. Secondly, the students are handed a set of printed documents pertaining to the topic, which they are intended to research to extend their understanding and knowledge about the topic. The students are then asked to write down suggestions on changes that can be made to the game to improve the functionality of the robot and make the game more realistic and useful as a learning tool..

Expected use of technology: In this stage, students are expected to use the technology in an exploratory way. They will interact with the robot in order to solve the task, discuss how the tool works, and share their ideas to each other. The groups are also expected to use the dashboard.

Expected student construction: a comprehensive log of collected data with user interactions, written markings/highlighting in the printed documents, written reflections about the tool, written reflections on changes that can be made to make the game more realistic and useful as a learning tool.

Expected group interactions: Discussion on the topic, exchange of personal experiences and reflections.

4.2 Phase 2: Define

In the “define” phase students define (narrow down / converge) certain features of the final product based on the information explored in phase 1. This involves, for example, setting criteria, making decisions, mapping user needs with specific features, and discarding ideas that seem less favorable than others. In this phase they are expected to use the project technology to ideate, share ideas (e.g. define game fields, consider ideas in context of the current functionality).

Duration: 20 minutes

Summary: Following the “discover”-step, the students should try to produce some overall thoughts and narrow them down to sufficient specificity. When they have defined 2-5 points that they want to prioritize, these points should be developed into an improvement plan for specific changes that can be made to improve the game. Changes that can be made include how the robot is controlled, how the robot is constructed, interaction with the platform, etc.

Expected use of technology: In this stage, students are expected to use the technology in an exploratory way. They will try to control the robot, discuss how the tool works, and share their ideas to each other. The groups are also expected to use the dashboard.

Expected student construction: a comprehensive log of collected data with user interactions, an improvement plan for changes that should be made to the block-code program that controls the robot and the user interface of the platform.

Expected group interactions: Ideate as a pair to come up with some initial ideas, all students express ideas, best ideas are included in the improvement plan.

4.3 Phase 3: Develop

In the "develop" phase students develop different prototypes (diverge) based on the possible improvements defined in phase 2. This involves, for example, implementing ideas, comparing solutions, and iterating on promising prototypes. In this phase they are expected to use the project technology to implement changes, run simulations and test functionality.

Duration: 1 hour

Summary: With the improvement plan resulting from the "define" step, students should try to implement improvements to the robot by interacting with the block code. Different alternatives to solving the specified changes should be implemented, and the students should compare these in regards to how well they improve functionality.

Expected use of technology: In this stage, students are expected to use the technology in an implementing way. They will try to improve how the robot is constructed and controlled, evaluate functionality and compare solutions. The groups are also expected to use the dashboard.

Expected student construction: a comprehensive log of collected data with user interactions, generated block coding implementation.

Expected group interactions: Cooperate as a group to implement improvements, discuss how functionality is changed, continuously make further improvements.

5 Assessment Procedures

Provide some suggestions for procedures, methods and tools that can facilitate the assessment of the teaching objectives stated at the beginning of the activity plan (e.g. post activity tests, reflective videos, student worksheets etc).

5.1 Material

Which materials will be used for assessment?

Data automatically collected by student interaction (keystrokes, mouse clicks, switching tabs, opening/closing the dashboard - all with timestamps),notes, highlighting in printed documents, final block code created by the students, group interviews with the students, pre- and post-test questionnaires.

5.2 Procedure

What assessment methodologies will be used?
Group evaluation. The final block code will be used to assess performance of the prototyping, while the notes taken will be assessed to evaluate the discover and define steps.

D Information Letter & Consent Form

Informasjonsbrev: Vil du delta i et forskningsprosjekt om "Design Thinking" og "Virtuell Robotikk"?

Dette er en forespørsel om deltakelse i et forskningsprosjekt som gjøres i forbindelse med en masteroppgave på NTNU. Masteroppgaven handler om hvordan nye metoder og teknologi kan implementeres for å forbedre utdanning. Samarbeidet mellom Vestsiden Ungdomskole og NTNU omfatter totalt to timer av faget "Teknologi og design" i uke 11 og 13. Dette dokumentet beskriver prosjektet, samt hva deltakelse innebærer.

Hensikten til prosjektet

Dette er et prosjekt relatert til introduksjon av Design Thinking og Virtual Robotics til tenåringsstudenter (14-18 år) ved hjelp av digitale verktøy og spillbaserte læringsaktiviteter. Fokuset er å forstå hvordan disse konseptene kan brukes til å designe engasjerende aktiviteter for studentene som kan bidra til effektiv læring.

Hvem er ansvarlig for forskningsprosjektet?

Sofia Papavlasopoulou (Førsteamanuensis ved NTNU) er ansvarlig for prosjektet. Denne forskningen vil bli utført i samarbeid med Institutt for datateknologi og informatikk ved Norges teknisk-naturvitenskapelige universitet (NTNU). Sofia kan kontaktes via e-post: spapav@ntnu.no, Sem Sælands vei 9, IT-bygget 146, mobilnummer: +47 45786588.

To forskningsassistenter vil også være involvert i prosjektet.
Øyvind Jalland Schjerven, e-post: oyvinjs@stud.ntnu.no, mobilnummer: +47 93604443 og Kristoffer Nyvoll, e-post: kristnyv@stud.ntnu.no, mobilnummer: +47 90413749, som for øyeblikket skriver masteroppgaven sin i informatikk, vil utføre datainnsamlingen. Prosjektansvarlig vil lagre og deretter ha tilgang til personopplysningene.

Hvorfor blir du bedt om å delta?

Vi søker elever i alderen 14-18 år for å kartlegge deres mening om å introdusere Design Thinking (DT) med Virtual Robotics (VR). Det er ikke behov for tidligere erfaring med noen DT- eller VR-konsepter, verktøy eller aktiviteter fra deltakerne.

Hva innebærer deltakelse for deg?

Studien vil finne sted fysisk i klasserommet. Hvis du deltar i studien, vil du besvare to korte spørreundersøkelser, samt delta i et intervju (for å gi tilbakemelding og meninger om verktøyene og aktivitetene knyttet til DT og VR). Svarene dine vil bli registrert elektronisk. Varigheten av å svare på undersøkelsen er maks 10 minutter, og intervjuet vil ta 10-20 minutter.

Deltakelse er frivillig

Deltakelse i prosjektet er frivillig. Hvis du velger å delta, kan du når som helst trekke tilbake ditt samtykke uten å gi en grunn. All informasjon om deg vil da bli gjort anonym. Det vil ikke være negative konsekvenser for deg hvis du velger å ikke delta eller senere bestemmer deg for å trekke deg. Deltakelse vil ikke ha noen påvirkning på "Teknologi og design"-faget.

Ditt personvern - hvordan vi vil lagre og bruke dine personlige data
Vi vil kun bruke dine personlige data til det eller de formålene som er spesifisert i denne informasjonsbrevet. Vi vil behandle dine personlige data konfidensielt og i samsvar med GDPR. Kun forskere som utfører denne studien vil ha tilgang til dine personlige data. Dataene vil bli lagret på en datamaskin som tilhører databehandleren (dvs. NTNU). Tilgang til data som er lagret på alle disse enhetene vil være passordbeskyttet. Vi vil erstatte ditt navn med en ID-kode. Listen over navn og tilhørende koder vil bli lagret separat fra resten av de innsamlede dataene. Deltakere vil ikke være gjenkjennelige i noen publikasjoner som følge av denne studien. Prosjektet er planlagt å avsluttes 12.06.23. Etter det vil dataene bli anonymisert.

Dine rettigheter
Så lenge du kan identifiseres i de innsamlede dataene, har du rett til å:
- få tilgang til, motta en kopi av, samt slette personlig data som behandles
- be om at feilaktige personlige data om deg blir korrigert/rettet
- sende en klage til Personvernombudet eller Datatilsynet angående behandlingen av dine personlige data

Hva gir oss rett til å behandle dine personlige data?
Vi vil behandle dine personlige data basert på ditt samtykke. Basert på en avtale med Institutt for datavitenskap ved Norges teknisk-naturvitenskapelige universitet (NTNU) har Sikt - Kunnskapssektorens tjenesteleverandør vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med GDPR.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål om prosjektet eller vil utøve dine rettigheter, kan du kontakte:
- Norges teknisk-naturvitenskapelige universitet via Sofia Papavlasopoulou på e-post: spapav@ntnu.no
- Vårt personvernombud: Thomas Helgesen på e-post: thomas.helgesen@ntnu.no eller på telefon: +47 93 07 90 38.
- NSD – Norsk senter for forskningsdata AS, på e-post: personverntjenester@nsd.no eller på telefon: +47 55 58 21 17.

Vennlig hilsen,

Sofia Papavlasopoulou	Kristoffer Nyvoll	Øyvind Jalland Schjerven
Prosjektleder	Masterstudent	Masterstudent

Samtykkeskjema
Jeg har mottatt og forstått innholdet i informasjonsbrevet. Videre samtykker jeg til at mitt barn deltar i forskningsprosjektet, derunder svarer på spørreundersøkelser og deltar i et intervju. Jeg gir mitt samtykke til at personopplysninger blir behandlet fram til prosjektslutt, ca. 12.06.2023

Signatur foresatt: ________________________

Hva er en robot?

En robot er en maskin eller et dataprogram som er i stand til å utføre oppgaver automatisk, uten menneskelig innblanding. Det er vanligvis programmert til å utføre spesifikke oppgaver ved hjelp av sensorer, motorer og andre mekaniske eller elektroniske komponenter. En robot kan utføre en rekke oppgaver, fra å montere biler på en fabrikk til å rense gulv på et kjøpesenter.

Roboter kan utformes på mange forskjellige måter, avhengig av oppgaven de skal utføre. Noen roboter er humanoid, som betyr at de har en menneskelig form, mens andre er mer maskinlignende i utseendet. De kan også variere i størrelse fra mikroskopiske nanoroboter til enorme industrielle roboter som kan fylle en hel fabrikk.

Roboter har mange fordeler, inkludert økt effektivitet, nøyaktighet og produktivitet. De kan også utføre farlige oppgaver, som å utforske farlige områder eller å arbeide i farlige miljøer som ekstrem varme eller kulde. Samtidig kan imidlertid roboter også skape bekymringer rundt arbeidsløshet, personvern og sikkerhet.

Hvordan kan en robot brukes i brannredning?

Robotteknologi har vist seg å ha mange bruksområder innenfor ulike sektorer. En av disse sektorene er brannredning. Med stadig økende fokus på å beskytte liv og eiendom mot branner, har teknologien utviklet seg for å møte behovene til brann- og redningstjenestene. Robotikk er en av de teknologiene som kan benyttes i brannredning, og her vil vi diskutere hvordan det kan brukes til å redde liv og eiendom i brannsituasjoner.

En av de viktigste måtene robotikk kan brukes i brannredning er gjennom brannroboter. Disse robotene er spesielt designet for å fungere i ekstreme varme- og røykforhold, og kan brukes til å utføre oppgaver som ellers ville vært for farlige for mannskapene. Brannroboter kan være utstyrt med ulike sensorer og kameraer som gir dem mulighet til å navigere i et røykfylt miljø og søke etter overlevende eller potensielle farer.

En av utfordringene i brannredning er å finne og redde overlevende som kan være fanget inne i en brennende bygning. Brannroboter kan bidra til å lette denne oppgaven ved å navigere gjennom bygninger og søke etter overlevende. Ved å bruke kameraer og sensorer kan robotene finne mennesker som kan ha problemer med å bevege seg eller puste på grunn av røyk og varme. Dette kan redde liv og bidra til å minimere skadeomfanget.

I tillegg til å søke etter overlevende kan brannroboter også brukes til å slukke branner. Dette kan gjøres ved å bruke roboter med ulike slukkemidler som for eksempel skum eller pulver. Disse robotene kan også ha ulike utstyr som vannkanoner som kan rettes mot brannkilder på en trygg og effektiv måte. Ved å bruke roboter til å slukke branner kan mannskapene i brann- og redningstjenesten holdes trygge og unngås farlige situasjoner som kan være livstruende.

Det er viktig å understreke at robotikk ikke er ment å erstatte menneskelige mannskaper i brann- og redningstjenesten, men heller bidra til å øke effektiviteten og sikkerheten. Brannroboter kan hjelpe til med å utføre oppgaver som kan være for farlige for mennesker å utføre, og samtidig gi mannskapene bedre situasjonsbevissthet og informasjon om brannsituasjonen.

En annen fordel med å bruke robotikk i brannredning er at det kan bidra til å redusere skadeomfanget på bygninger og eiendommer. Ved å bruke roboter til å slukke branner kan man unngå at brannen sprer seg og skader andre områder av bygningen eller eiendommen. Dette kan bidra til å minimere de økonomiske og menneskelige kostnadene ved branner og øke sjansen for at bygningene kan bli gjenoppbygd og gjenbrukt i fremtiden.

Roboter kan også brukes til å transportere verdifulle gjenstander ut av en brennende bygning på en trygg og rask måte. For eksempel kan en drone fly ut gjenstander som malerier eller viktige dokumenter fra øverste etasje av en bygning og transportere dem til et trygt sted uten risiko for skade.

Fordeler ved bruk av roboter

I en verden der teknologien utvikler seg raskere og raskere, ser vi stadig flere tilfeller av at roboter og automatisering brukes i farlige situasjoner der mennesker tidligere har vært den eneste løsningen. Brannredning er en av disse situasjonene, og bruk av roboter i redningsoperasjoner har mange potensielle fordeler.

En av de største fordelene ved bruk av roboter til brannredning er at de kan utføre oppgavene på en mye mer effektiv måte enn mennesker. Robotene kan bevege seg raskere og mer presist i farlige områder, og kan dermed redde liv raskere og mer effektivt. De kan også utføre oppgaver som kan være for farlige for mennesker, som å utforske strukturer som kan være ustabile eller usikre.

En annen fordel er at roboter kan være utstyrt med sensorer og kamerasystemer som gir redningsmannskapene bedre oversikt over situasjonen. Dette kan hjelpe dem med å ta mer informerte beslutninger og redde liv på en mer effektiv måte. I tillegg kan robotene ha ulike verktøy og utstyr som kan hjelpe med å slokke branner og redde personer fra farlige situasjoner.

En annen fordel er at roboter ikke er utsatt for de samme risikoene som mennesker i brannredningssituasjoner. Mens menneskelige redningsarbeidere kan være utsatt for farlige gasser, ekstreme temperaturer og andre farer, kan robotene tåle slike forhold uten å bli skadet. Dette betyr at roboter kan utføre oppgaver i farlige områder uten å sette liv i fare.

En annen fordel er at roboter kan være programmerbare og kontrollerbare på avstand. Dette betyr at de kan sendes inn i farlige områder mens redningsmannskapene kan kontrollere dem fra et trygt sted. Dette gir en ekstra sikkerhetsmargin for redningsmannskapene og reduserer risikoen for skader og dødsfall i redningsoperasjoner.

Til slutt kan bruk av roboter til brannredning være kostnadseffektivt på lang sikt. Selv om det kan være dyrt å utvikle og implementere roboter, kan de redusere kostnadene ved skader og tap av menneskeliv i fremtiden. I tillegg kan roboter være i stand til å utføre oppgaver raskere og mer effektivt enn mennesker, noe som kan redusere kostnadene i redningsoperasjoner.

Alt i alt er det mange fordeler ved bruk av roboter til brannredning. Robotene kan være mer effektive, kan utføre farlige oppgaver uten å sette menneskeliv i fare, og kan være kostnadseffektive på lang sikt. Selv om det er noen utfordringer med å utvikle og implementere roboter, kan disse fordelene bidra til å redde liv og gjøre brannredningssituasjoner tryggere for alle involverte.

Utfordringer ved bruk av roboter i brannredning

Brannredning er en farlig og krevende oppgave som kan være livstruende for redningsmannskapene. Derfor har det vært stor interesse for å utvikle roboter som kan utføre brannredning oppgaver på vegne av mennesker. Selv om det er mange fordeler med å bruke roboter i slike farlige situasjoner, er det også mange utfordringer som må løses for at de skal være effektive.

En av de største utfordringene med å bruke roboter til brannredning er å gjøre dem robuste nok til å takle utfordrende miljøer. Brannmiljøer kan være ekstremt varme og røykfylte, og det kan være vanskelig for roboter å navigere i slike forhold. Roboter må ha sensorer og kamerasystemer som fungerer selv i disse miljøene og har mulighet til å oppdage objekter og navigere rundt hindringer.

En annen utfordring er å sikre at robotene kan utføre de nødvendige oppgavene. Brannredning involverer mange forskjellige aktiviteter, som å finne og redde personer, slokke branner og undersøke strukturer for farer. Det er viktig å utvikle roboter som er i stand til å utføre disse oppgavene på en effektiv og pålitelig måte. Det er også viktig å sikre at robotene ikke utgjør en fare for mennesker under redningsoperasjoner.

En annen utfordring er å sikre at robotene kan kommunisere med menneskelige redningsarbeidere. Selv om roboter kan være en stor hjelp i brannredningsoperasjoner, kan de ikke erstatte menneskelig interaksjon helt. Det er viktig å utvikle roboter som kan kommunisere med menneskelige redningsarbeidere og samarbeide med dem for å utføre oppgavene på en sikker og effektiv måte.

En annen utfordring er å sikre at robotene kan fungere i ulike miljøer. Branner kan oppstå i mange forskjellige typer bygninger og strukturer, og robotene må være i stand til å navigere i alle disse miljøene. Det er også viktig å sikre at robotene kan takle ulike værforhold og klima.

Til slutt er det viktig å tenke på kostnadene ved å utvikle og implementere roboter til brannredning. Teknologien som trengs for å lage robuste og pålitelige roboter kan være dyre, og det kan være utfordrende å rettferdiggjøre kostnadene hvis det ikke er mange branner eller redningsoperasjoner der robotene vil bli brukt.

Alt i alt er det mange utfordringer som må løses for å gjøre roboter til en effektiv løsning for brannredning. Det er viktig å ta hensyn til alle disse utfordringene når man utvikler og implementerer roboter til brannredning, for å sikre at de er i stand til å redde liv og redusere risikoen for menneskelige redningsarbeidere.

Brannredning

Brannmannskap står overfor en av de farligste og mest utfordrende jobbene som finnes. De må redde liv og eiendom i farlige situasjoner som branner i høye bygninger, kollapsende konstruksjoner, gasslekkasjer eller eksplosjoner. I slike situasjoner kan brannmannskapets egne liv også stå på spill, og det kreves spesielle ferdigheter, utstyr og taktikk for å utføre en sikker og effektiv evakuering.

Risiko

En av de største risikoene som brannmannskap står overfor i farlige evakueringssituasjoner, er eksponering for giftige gasser, røyk og kjemikalier. Brannmannskapet må ofte bevege seg gjennom tette røyk- og gasskyer, og kan bli utsatt for giftige stoffer som karbonmonoksid, hydrogensulfid og cyanid. Dette kan føre til alvorlige helseproblemer, inkludert kvelning, brannskader og hjerneskade.

En annen risiko er at bygninger eller strukturer kan kollapse mens brannmannskapet utfører evakuering. Dette kan skje hvis bygningen ikke er tilstrekkelig støttet opp eller er svekket av brannen. Brannmannskapet må derfor være oppmerksom på farene ved å bevege seg i og rundt en skadet bygning, og må kunne identifisere strukturelle risikoer og treffe tiltak for å minimere risikoen for kollaps.

I tillegg kan brannmannskap stå overfor farene ved eksplosjoner, særlig i situasjoner hvor det er gasslekkasjer eller eksplosive stoffer i bygningen. Slike eksplosjoner kan føre til alvorlige skader eller dødsfall for både brannmannskapet og personene de prøver å evakuere.

En av de viktigste oppgavene til brannmannskapet er å redde mennesker fra brennende bygninger. For å gjøre dette på en effektiv og sikker måte, er det flere faktorer som må tas i betraktning. Brannmannskapet må kunne håndtere evakuering av mennesker på en sikker måte, og samtidig unngå farlige situasjoner som kan føre til skader eller dødsfall.

I farlige evakueringssituasjoner, som for eksempel når det er røyk eller farlige gasser, kan brannmannskapet være utsatt for helsefarer som kan føre til alvorlige skader eller død. Brannmannskapet må være i stand til å vurdere risikoen og ta avgjørelser raskt og effektivt. De må også ha tilgang til nødvendig medisinsk utstyr og opplæring i førstehjelp for å kunne håndtere skadde mennesker.

Utstyr

For å minimere risikoen og sikre en effektiv og sikker evakuering, er det viktig at brannmannskapet er godt forberedt og trent på å håndtere farlige situasjoner. De må ha tilgang til riktig utstyr og verneutstyr, og må være i stand til å identifisere farer og risikoer og til å iverksette tiltak for å minimere disse. Det er en rekke ulike typer utstyr som kan være nødvendig for brannmannskap i redningssituasjoner.

Brannbekjempelsesutstyr: Dette inkluderer brannslanger, brannslukkingsapparater og skumkanoner som brukes for å slukke brannen. Brannmannskap må vite hvordan de skal bruke dette utstyret riktig for å sikre en trygg brannbekjempelse.

Pusteutstyr: Dette utstyret brukes når røyk og farlige gasser er til stede i området, og gjør det umulig å puste. Det kan omfatte trykkluftflasker og ansiktsmasker, eller selvstendige pustemasker.

Redningsutstyr: Brannmannskap trenger utstyr som hjelper dem med å redde personer fra farlige situasjoner. Dette inkluderer tau, redningsvester, kroker og sikringsutstyr for å hjelpe med å transportere personer til sikkerhet.

Verneutstyr: Brannmannskapet må beskytte seg selv mot varme og brannskader, og må derfor bruke riktig verneutstyr som brannhjelm, brannfrakk, brannhansker, brannstøvler, brannmaske og annet beskyttelsesutstyr.

Kommunikasjonsutstyr: Brannmannskapet må være i stand til å kommunisere med hverandre og med andre redningstjenester. Dette kan inkludere walkie-talkies, mobiltelefoner, satellittelefoner og andre kommunikasjonsmidler.

Termisk avbildning: Dette er et kamera som kan registrere varmestråling og brukes til å identifisere varmekilder, personer og objekter som er skjult av røyk og tåke.

Løfte- og bæreutstyr: Brannmannskapet må kunne bære og løfte tunge gjenstander og personer. Dette kan omfatte løftebåre, hydraulisk løfteutstyr og andre verktøy som kan hjelpe med å løfte og flytte tunge gjenstander.

Belysning: Dette er viktig når redningsoperasjonene utføres i mørke omgivelser, og inkluderer lyskastere og lommelykter.

Verktøy: Dette inkluderer økser, brekkjern, hammer og andre verktøy som kan hjelpe brannmannskapet med å bryte seg inn i bygninger, åpne dører og vinduer og utføre andre oppgaver.

Stresshåndtering og utfordringer

For å kunne håndtere stressende situasjoner og ta riktige beslutninger i kritiske øyeblikk under brannredning, må brannmannskapet være forberedt på ulike utfordringer. Tidspress, farlige forhold, fysiske og mentale krav, kommunikasjon og endringer i situasjonen er noen av disse utfordringene. Brannmannskapet må ha regelmessig trening og utdanning for å kunne takle disse utfordringene og ta riktige beslutninger.

Brannmannskap har ofte begrenset tid til å utføre oppgavene sine. De må kunne raskt identifisere og prioritere oppgaver og samarbeide effektivt for å få jobben gjort.

Brannmannskapet må ofte jobbe i farlige og uforutsigbare omgivelser. De må være forberedt på å håndtere uventede hindringer og farer, og ta raske beslutninger for å beskytte seg selv og de som er involvert i redningsoperasjonen.

For å kunne takle disse utfordringene er det viktig at brannmannskapet får regelmessig trening og utdanning. De må også ha tilgang til adekvat støtte og ressurser for å håndtere eventuelle psykiske og fysiske utfordringer som kan oppstå under brannredning. Det er også viktig at brannmannskapet har en god kommunikasjonsstruktur og at de kan samarbeide effektivt som et team for å takle stressende situasjoner og ta riktige beslutninger i kritiske øyeblikk.

En av de største utfordringene for brannmannskapet er å kunne kommunisere effektivt i stressende situasjoner. De må ha en god kommunikasjonsstruktur som tillater rask og klar kommunikasjon mellom alle medlemmer av teamet. De må også være i stand til å samarbeide effektivt som et team for å kunne takle de ulike oppgavene som oppstår under en brannredning.

Endringer i situasjonen er også en stor utfordring for brannmannskapet. Situasjonen kan endre seg raskt, og brannmannskapet må være i stand til å tilpasse seg raskt og ta riktige beslutninger. Dette krever både ferdigheter og evnen til å tenke rasjonelt og kreativt under press. Brannmannskapet må også være i stand til å prioritere oppgaver, slik at de mest kritiske oppgavene blir håndtert først.

Fysiske og mentale krav er også en stor utfordring for brannmannskapet. Arbeidet med å bekjempe brann kan være fysisk krevende, og brannmannskapet må være i god fysisk form for å kunne håndtere dette. Samtidig kan stressende situasjoner og utfordrende beslutninger være mentalt krevende, og brannmannskapet må være forberedt på dette.

For å kunne takle disse utfordringene på en effektiv og sikker måte, er det nødvendig med regelmessig trening og opplæring. Dette vil bidra til å styrke ferdighetene og evnene til brannmannskapet, og gjøre dem bedre rustet til å takle de utfordringene som kan oppstå under en brannredning.

Alt i alt, brannmannskapet står overfor en svært utfordrende og farlig jobb, og det er viktig at de har tilgang til riktig utstyr, utdanning og trening for å kunne håndtere situasjoner på en effektiv og sikker måte. Deres arbeid er avgjørende for å beskytte liv og eiendom, og de fortjener vår takknemlighet og respekt.

F Log Data Analysis Python Script

```python
import csv

# Load data from CSV file
with open('session1.csv', newline='') as csvfile:
    data = list(csv.reader(csvfile))

# Loop through rows
for row in data:
    tempTimestampOpened = 0
    tempTimestampClosed = 0
    dbOpen = False
    groupID = row[1]

    # Initialize variables
    numTriggers = len(row)//2
    totTimeDbMillis = 0
    dbOpenedCount = 0
    # ... also initialized loads of other varibles

    # Loop through data in row
    for i in range(len(row)):
        if row[i] == "ArrowUp" or row[i] == "ArrowDown" or row[i] == "ArrowLeft"
        ↪ or row[i] == "ArrowRight":
            arrowCount += 1
        elif row[i] == "dashboardOpened":
            dbOpenedCount += 1
            tempTimestampOpened = int(row[i-1])
            dbOpen = True
        elif row[i] == "dashboardClosed" and dbOpen:
            dbClosedCount += 1
            tempTimestampClosed = int(row[i-1])
            totTimeDbMillis += tempTimestampClosed - tempTimestampOpened
            dbOpen = False
        elif row[i] == "hubButtonup" or row[i] == "hubButtonenter" or row[i] ==
        ↪ "hubButtondown" or row[i] == "hubButtonleft" or row[i] ==
        ↪ "hubButtonbackspace" or row[i] == "hubButtonright":
            hubButtonsCount += 1
        elif row[i] == "KeyA" or row[i] == "KeyD" or row[i] == "KeyW" or row[i]
        ↪ == "KeyS":
            aswdKeys += 1
        # ... also had elif increments for all other variables
        else:
            if not row[i].isnumeric():
                miscArr.append(row[i])

    # Convert totTimeDbMillis to seconds and whole minutes
    totTimeDbSeconds = totTimeDbMillis / 1000
    totTimeDbMinutes = totTimeDbSeconds // 60

    # Print results
    print("ID:", groupID)
    print("numTriggers:", numTriggers)
    # ... also printed the rest of the variables
```

G PCA Python Script

```python
import numpy as np
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler

# Define the data matrix
data = np.array([
    [543, 25, 25, 4, 205, 61, 30, 0, 0, 0, 22, 3, 102, 0, 0, 14, 19],
    [281, 12, 11, 1, 78, 10, 7, 0, 6, 29, 32, 1, 76, 1, 2, 0, 1],
    [186, 7, 9, 4, 29, 5, 2, 0, 5, 5, 4, 3, 91, 0, 0, 4, 3],
    [288, 16, 15, 0, 77, 23, 19, 0, 8, 4, 4, 7, 47, 1, 0, 5, 0]
])

# Standardize the data
scaler = StandardScaler()
data_standardized = scaler.fit_transform(data)

# Perform PCA
pca = PCA(n_components=2)
principal_components = pca.fit_transform(data_standardized)

# Print the results
print("Explained variance ratio:", pca.explained_variance_ratio_)
print("Principal components:\n", principal_components)
```

H Modal Content

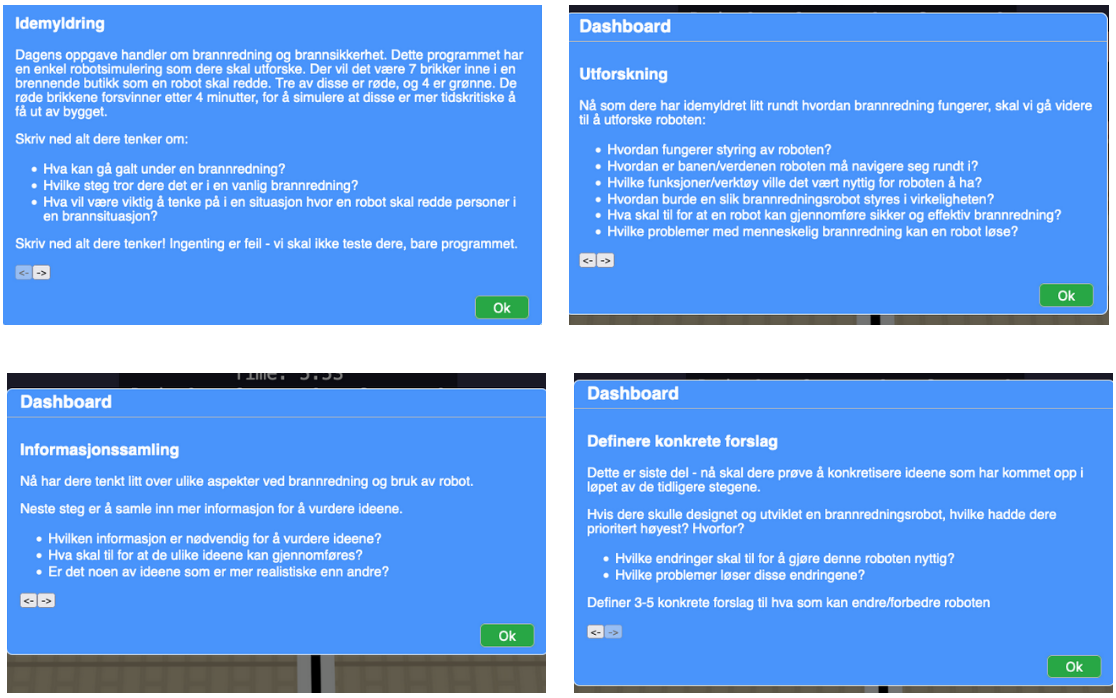
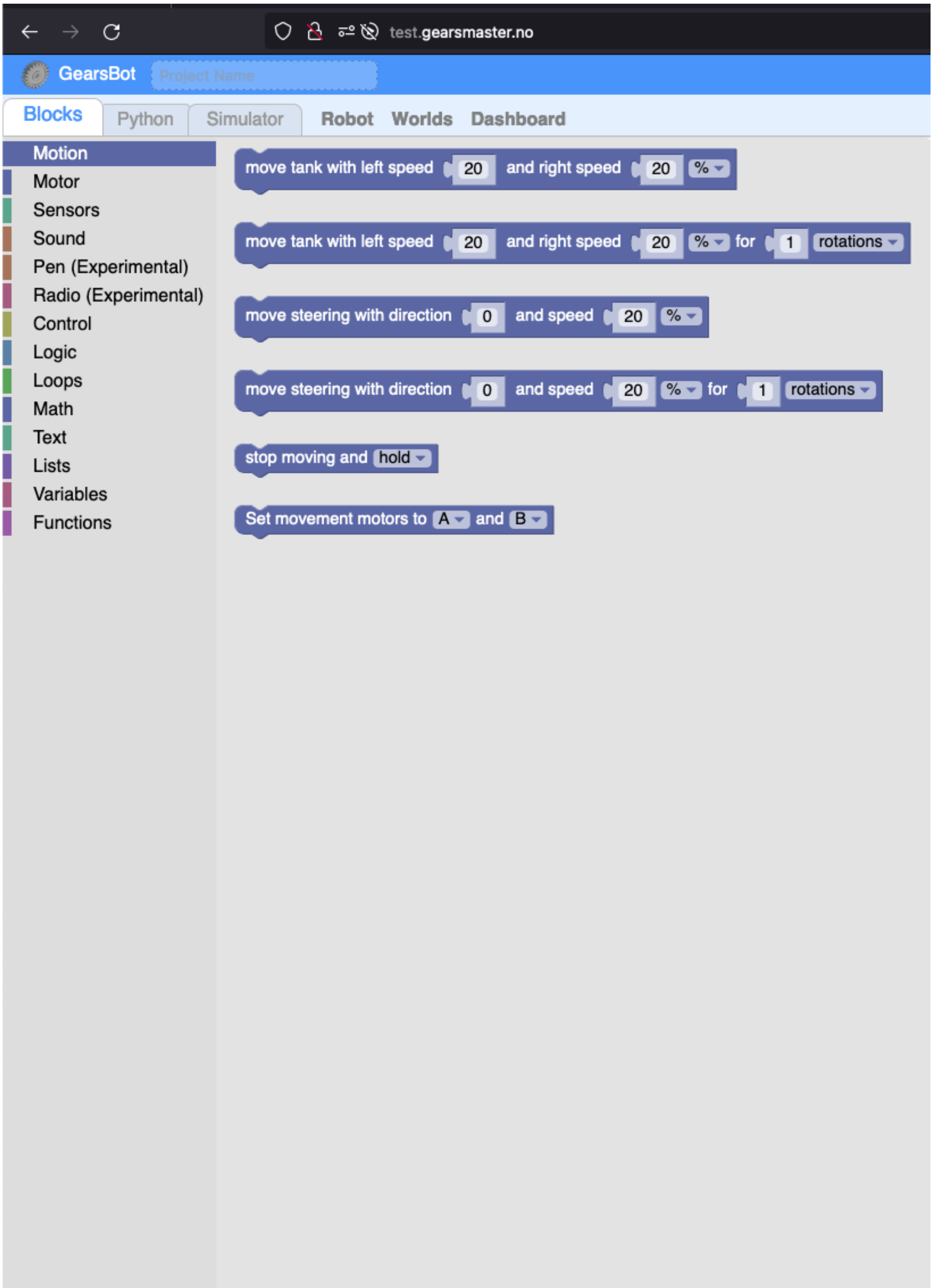
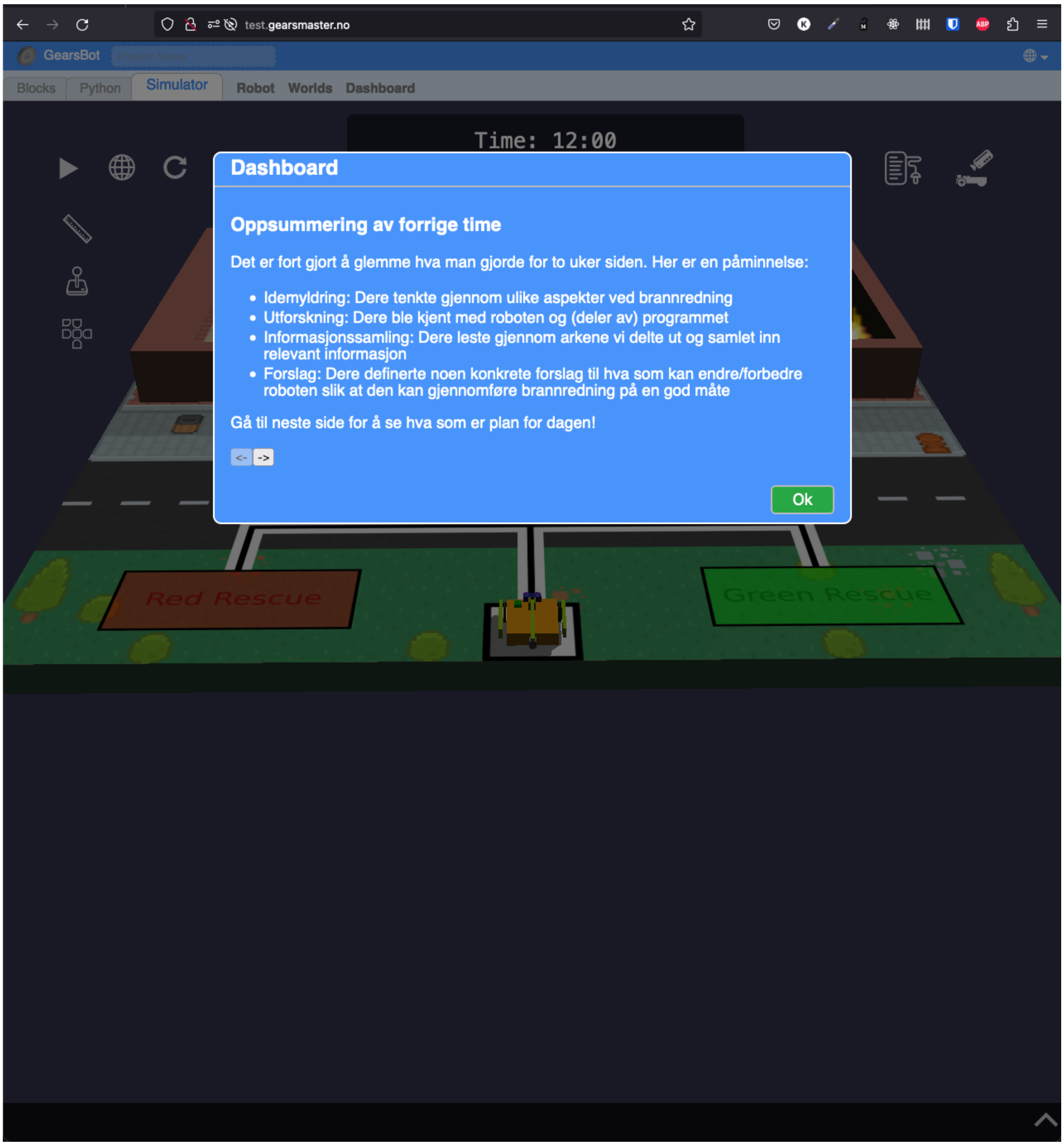


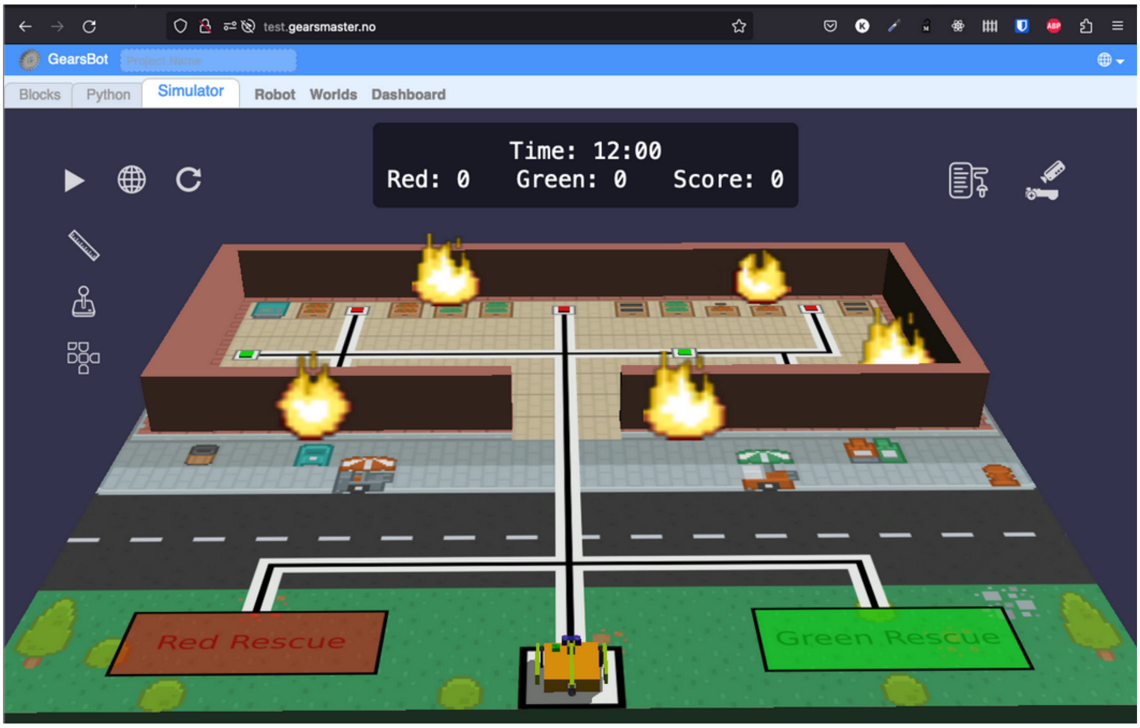
Figure 17: Modal content from the first user-testing session.

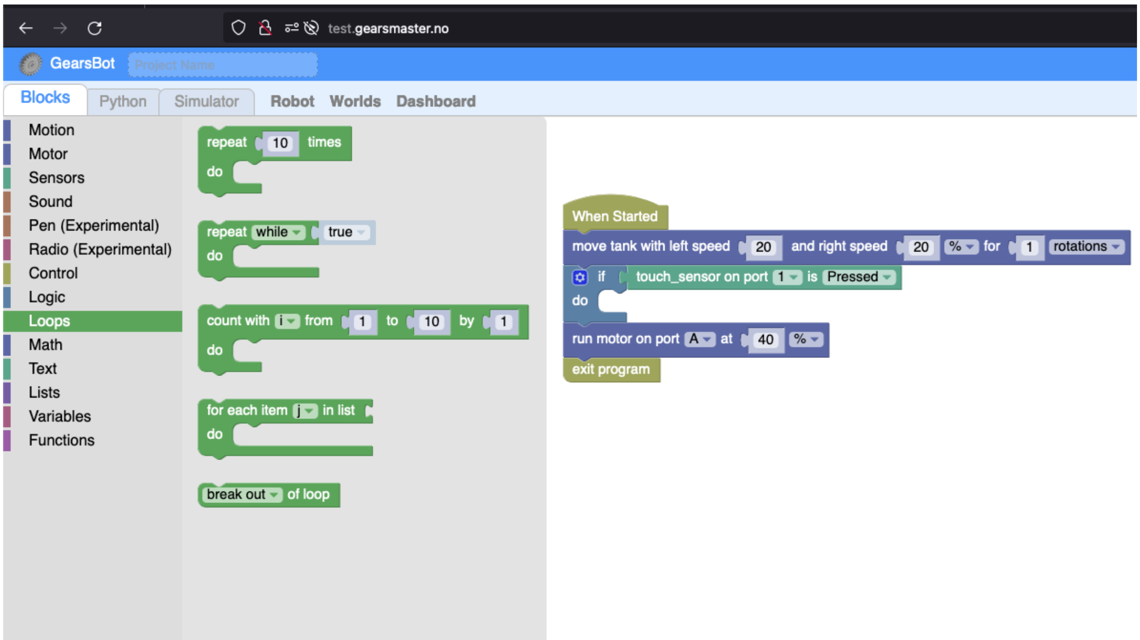
Figure 18: Modal content from the second user-testing session.

I Screenshots of the Platform




test.gearsmaster.no
GearsBot
Blocks
Python
Simulator
Robot
Worlds
Dashboard
Time: 12:00
Dashboard
Oppsummering av forrige time
Det er fort gjort å glemme hva man gjorde for to uker siden. Her er en påminnelse:
Idemyldring: Dere tenkte gjennom ulike aspekter ved brannredning
Utforskning: Dere ble kjent med roboten og (deler av) programmet
Informasjonssamling: Dere leste gjennom arkene vi delte ut og samlet inn relevant informasjon
Forslag: Dere definerte noen konkrete forslag til hva som kan endre/forbedre roboten slik at den kan gjennomføre brannredning på en god måte
Gå til neste side for å se hva som er plan for dagen!
<-
->
Ok
Red Rescue
Green Rescue


test.gearsmaster.no
GearsBot
Blocks
Python
Simulator
Robot
Worlds
Dashboard
Time: 12:00
Red: 0
Green: 0
Score: 0
Red Rescue
Green Rescue

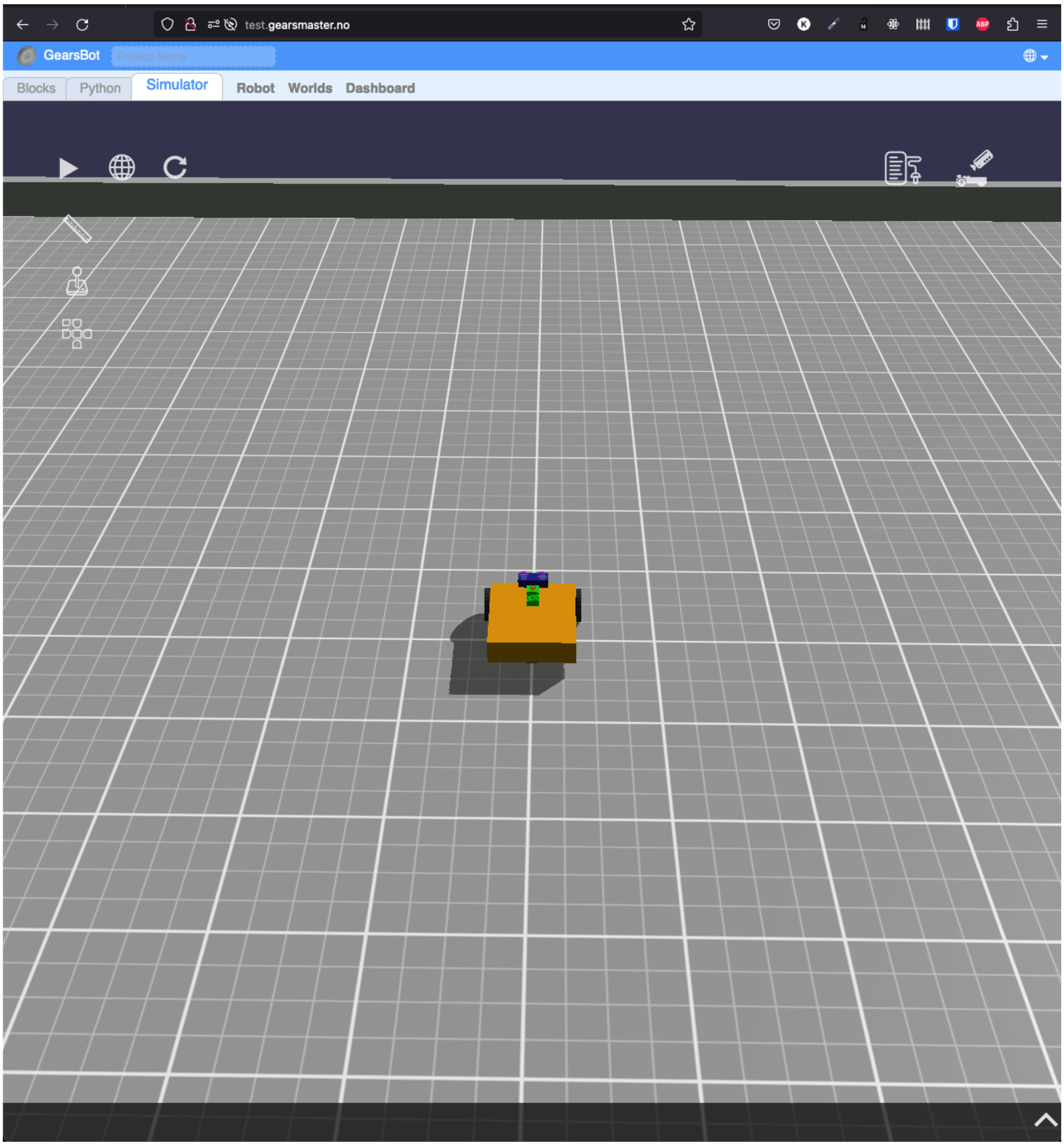

test.gearsmaster.no
GearsBot
Blocks
Python
Simulator
Robot
Worlds
Dashboard
Motion
Motor
Sensors
Sound
Pen (Experimental)
Radio (Experimental)
Control
Logic
Loops
Math
Text
Lists
Variables
Functions
repeat 10 times
do
repeat while true
do
count with i from 1 to 10 by 1
do
for each item j in list
do
break out of loop
When Started
move tank with left speed 20 and right speed 20 % for 1 rotations
if touch_sensor on port 1 is Pressed
do
run motor on port A at 40 %
exit program

test.gearsmaster.no

GearsBot

Blocks | Python | Simulator | Robot | Worlds | Dashboard

```python
#!/usr/bin/env python3

# Import the necessary libraries
import time
import math
from ev3dev2.motor import *
from ev3dev2.sound import Sound
from ev3dev2.button import Button
from ev3dev2.sensor import *
from ev3dev2.sensor.lego import *
from ev3dev2.sensor.virtual import *

# Create the sensors and motors objects
motorA = LargeMotor(OUTPUT_A)
motorB = LargeMotor(OUTPUT_B)
left_motor = motorA
right_motor = motorB
tank_drive = MoveTank(OUTPUT_A, OUTPUT_B)
steering_drive = MoveSteering(OUTPUT_A, OUTPUT_B)

spkr = Sound()
btn = Button()
radio = Radio()

color_sensor_in1 = ColorSensor(INPUT_1)
ultrasonic_sensor_in2 = UltrasonicSensor(INPUT_2)
gyro_sensor_in3 = GyroSensor(INPUT_3)
gps_sensor_in4 = GPSSensor(INPUT_4)
pen_in5 = Pen(INPUT_5)

motorC = LargeMotor(OUTPUT_C) # Magnet

# Here is where your code starts

tank_drive.on_for_rotations(20, 20, 1)
if touch_sensor_in1.is_pressed:
    pass
motorA.on(40)
exit()
```


test.gearsmaster.no
GearsBot
Blocks
Python
Simulator
Robot
Worlds
Dashboard

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