Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

Lars Møster

Designing Games that Teach Data Literacy

Master's thesis in Informatics
Supervisor: Monica Divitini
July 2020

NTNU
Norwegian University of Science and Technology

Designing Games that Teach Data Literacy

Master thesis - Informatics
Supervisor: Monica Divitini
1st July, 2020

LARS MØSTER

DEPARTMENT OF COMPUTER SCIENCE

NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY (NTNU)

TRONDHEIM,

LARS.MOSTER@HOTMAIL.COM

NTNU
Norwegian University of
Science and Technology

Abstract

The growing importance of data in the 21st century can not be overstated; data is becoming fundamental to the ways we understand, create, and communicate. Despite its importance, current school curricula do not focus on data literacy (DL), the ability to read, understand, and use data. Expanding data education is also difficult, because teachers lack the necessary knowledge about this new subject. Innovative teaching tools are needed to help bridge the data knowledge gap — for teachers and for students. Data is an essential pillar under the Information and Communications Technologies (ICT) that have radically changed how we interact with the world, over the last two decades, through smartphones, computers, and the internet. Though these new computer technologies give rise to challenges of competence and understanding, they may also provide the tools to meet these challenges, in the form of technological innovation.

In this project, a Design-Science approach was used to explore the how DL educational games could be designed to engage secondary school students. The research also explored what challenges students face learning DL, and designing for classroom integration, as well as learning goals for teaching DL with a focus on sensors. A systematic literature review was conducted. Game experts, teachers and students were interviewed, to explore the design of DL games. The interview results indicated big potential for educational games, which is also consistent with literature explored in this report.

A Game Design Space Document (GDSD) was created – a document to explore the design space of DL educational games. The document was entitled Data Master, and had the aim of facilitating design process of DL educational games, based on research. Data Master, the GDSD, is intended to be read by game designers, to help in the creation of games teaching DL. The GDSD was created through an iterative design process, with feedback from game designers.

Table of Contents

List of Tables

List of Figures

Abbreviations

IT	=	Information Technology
ICT	=	Information and Communication Technology
DL	=	Data Literacy
GDD	=	Game Design Document
GDSD	=	Game Design Space Document
NSD	=	Norwegian Centre for Research Data
Edu	=	Education/Educational
Dev	=	Developer/Development

Chapter 1

Introduction

This chapter introduces the problem with the motivation and context behind this thesis. The chapter then lists research questions, elaborates on the choice to focus on sensors. Following this is an outline of the design-science approach used, and after that presents and overview of the contributions from this research.

1.1 Motivation

There is an abundance of data in the world today, and the amount is inexorably growing. The increasing use of computer technologies allows for faster and cheaper data collection, transfer, and analysis. In the modern world, data is omnipresent. ”Data is everywhere: your government, your web server, your business partners, even your body” writes Loukides (2012) in *What is Data Science* continuing: ”...we’re finding that almost everything can (or has) been instrumented” . Since 2012, the field has only grown, and terms such as ’Big Data’ and ’Data Science’ are flourishing in the tech industry. The more data being generated, the bigger the potential for its use. The diffusion of technology like smartphones, tablets, computers, and other electronic equipment has made sensors plentiful in our lives. ”We have massive amounts of data about many aspects of our lives, and, simultaneously, an abundance of inexpensive computing power” Schutt and O’Neil C. (2013).

As learning about data continues increase in importance, collecting data has never been easier. All of this data gives us tremendous potential. Yet in schools there is little

focus on data – and especially how it can be used. Though some higher level educational institutions have started offering classes in data science, in the lower levels of education, almost no effort is put into understanding what data is, and how to use it. This leaves students lacking data literacy which could render them unprepared for a world where the importance of data increases by the day.

In the curricula of Norwegian secondary schools, data literacy is not a focus, despite its importance. In Norway, the updated official learning goals aim to increase digital competence, giving some focus to digital skills like algorithmic thinking, and programming (see appendix A.2). However implementing changes to subject in schools takes time. Another factor that is keeping DL education minimal is the lack of teachers that teach the subject.

In their 2019 master thesis, Holst and Magnussen report that a way to meet the demand for computer technology skills in schools is to use games as a teaching tool Holst and Magnussen (2019). Games in education is a developing field of research, and though we now know more than ever about how to use games that teach, much is yet to be learned as educational games start to be used, and find their way into schools. This project is meant to be another step on the way of understanding how to use educational games to teach important digital skills. Taking on data literacy, this project explores how games can be designed to teach data literacy.

1.1.1 What is Data Literacy (DL)?

Defining DL is important to clarify the problem. However a more thorough analysis of the definition will be presented in the problem elaboration (see section 2.5. From a Wolff et al. (2017) article, DL is defined as: ”to select, clean, analyse, visualize, critique, and interpret data, as well as being able to communicate stories from data, or use data as part of a design process”

Data Master focuses primarily on sensor data, and the definition of data literacy used will therefore only include a subset of the broader data literacy toolbox. So for the purposes of this project data literacy is knowing **what data is**, how to **collect** it, how to **analyze** it, and how to **use** it. Knowing **what data is** includes being able to read data and understand how it represents a measurement of something in the world. **Collecting** data involves using sensors (or other means), to create and acquire data and then to store and manage it. **Analyzing** data involves being able to draw conclusions based on data, through either aggregating, comparing, sorting, or other analytical tasks. **Using** data is simply taking the insights gained from analyzed data and applying it to solve problems, or to support

arguments.

1.2 Context

This research is done as a masters project at the Norwegian University of Science and Technology (NTNU), Department of Computer Science. The project is supervised by Dr. Monica Divitini, and inspired by research from her lab, as well as other contributors to the field. The thesis statement was devised by the author of this report, in cooperation with professor Divitini.

1.3 Research Questions

***RQ1**: How should games be designed for teaching data literacy to Norwegian secondary school students?*

This project mainly explores the design of educational games targeting Norwegian secondary school students. Norwegian students were chosen as the target group because the research was conducted in Norway. Interviews and testing could thus be done with local teachers and students. Secondary school (grades 8-13) was chosen because these levels of education include some use of data (eg. statistics see curricula in appendix A.3.1) , indicating that the topic is appropriate for this level.

***RQ1.1**: How can data literacy games be designed to be engaging for Norwegian secondary school students?*

Engagement is crucial for learning. A big upside to using games as a tool is the element of novelty. "...effective and meaningful learning may not take place if these technologies are only used in traditional ways" wrote Spikol and Milrad (2008), about the effects of novel ways to learn. "One of the advantages of using certain types of computer game in education is their ability, for many learners, to engender engagement and motivation, which contributes to effective learning" Whitton (2011). Games can be an engaging medium. Understanding how to take advantage of game the game engaging is therefore a key research goal for this project.

***RQ1.2**: What challenges do Norwegian secondary school students face when learning data literacy?*

Understanding what challenges students in the target group face when learning DL is

important for the game's design. Good educational games should understand the learning challenges of the material, and design to minimize these challenges. Understanding student challenges is also important for game design, to know how difficult to make the gameplay. Therefore this research question is explored in the thesis.

***RQ1.3**: What are key concerns when designing DL educational games for the classroom context?*

For educational games, classroom deployment is one important way to show relevance and be useful. Therefore this project also addresses the question of how classroom deployment affects design. To understand the classroom context, teacher needs must also be addressed. Using games for education is a new and not yet fully explored paradigm.

***RQ1.4**: What should be the learning goals for a game teaching sensor data literacy?*

This project aims to understand how to teach data literacy through games, focusing on the aspect of using sensors. Learning goals had to be established, to clarify what the games could be able to teach. This also defined what data literacy improvement looked like. Being clear about the skills intended to be improved by an educational game is essential both for its design, and for the measurement of success.

As will be explored in the literature review (see chapter 3), there are many aspects of data literacy for which educational games could be made. However this research project focuses specifically on sensor data. Sensor data is data collected by the use of a sensor, a device which measures a phenomenon in the natural world. The main reason for this focus on sensor data is because sensors are familiar to secondary school students. Compared to something new and abstract like personal data collected through browser activity, which is a new and complicated phenomenon, students may be used to seeing a thermometer, be familiar with the concept of a motion sensor, or find the use of a pollution sensor more intuitive. Data is an abstract concept, which can be difficult to understand for students, so by focusing on sensor, the aim is to make the data as concrete and tied to the real world as possible. This also ties into official educational goals from Norwegian curricula, which focus on sustainability and the environment. Sensors can easily be tied to subject matter which promotes sustainability. Another reason for the focus on sensor data in this project, is the lack of DL initiatives exploring the use of sensors. As will be explored in the literature review, there are examples of educational games teaching data literacy, although none of them focus on sensor data literacy. This focus therefore makes the project distinct from other research in this area.

Another important reason for using sensors was the ability for ordinary people to apply

their knowledge in a constructive way. Knowing how sensors work, and how to use them is not only a theoretical advantage when understanding data as a whole, but is also an applied skill which is useful.

1.4 Research Methods — Design-Science

This project falls under the discipline of design-science. In the article ”Design Science in Information Systems Research” Hevner et al. (2004) sum up the paradigm as such: ”The design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts.” This project explores the design of educational games, by creating a design space document. The document focuses on teaching data literacy through sensors to students in secondary school. The document, Data Master, is an innovative artifact aiming to solve a specific problem, and using the design-science research method is therefore useful. To quote Alan Hevner: ”The synergy between design-science and Behavioural science is so important in our field [Computer Science], and in other fields as well” [1].

In another important article, ”A Three Cycle View Of Design Science Research”, Hevner describes the design process with a three cycle view Hevner (2007). These cycles tie together environment, research, and knowledge base, and is depicted at 1.1. These three cycles form the basis for the design-science research method — they are: Relevance, Design, and Rigor. Ensuring that each of these cycles are satisfactorily addressed throughout the project is central to design-science research.

The relevance cycle for this project covers interviews with experts, and with users. . The design also incorporates elements from the curricular plan for Norwegian education (see appendix A.3.1 and A.2), to ground the project in relevant learning objectives. The design cycle involves an iterative process cycling through: ideation, conceptualization, feedback, adaptation, and implementation. Rigor in this project is done through the problem elaboration, the grounding analysis in literature, the theory based approach, and includes additions to the knowledge base through qualitative analysis.

[1]- Alan Hevner — `https://www.youtube.com/watch?v=gdCYH_a4hzY`

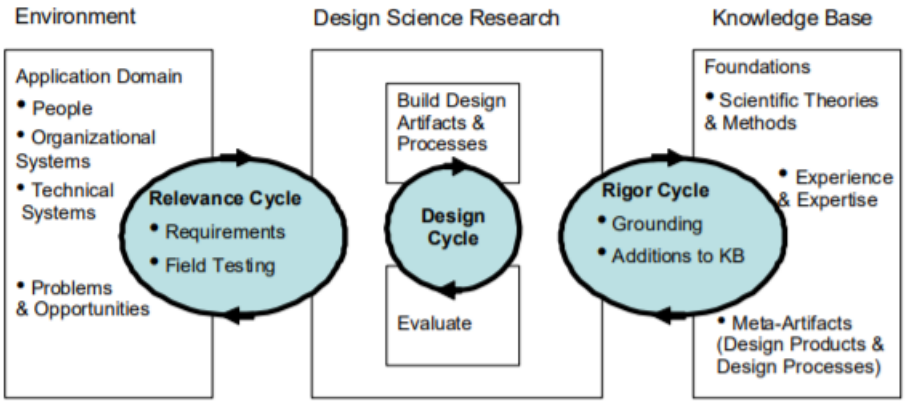


Figure 1.1: Three Cycle Design View

1.5 Results

The main contribution of this master thesis is Data Master, the GDSD. The document builds on all the work described in this report. Among this work there are several smaller contributions. A diagram showing the research process from a macro view is found 1.2. The process of creating the final contribution is described in chapter 7, and the GDSD itself is chapter 8.

This master thesis presents several smaller contributions which contribute towards the final GDSD. These contributions are also additions to the knowledge base:

- A problem elaboration exploring the design of DL games
- A literature review exploring the use of educational games to teach data literacy (DL)
- A set of interviews with teachers and students, to understand the educational perspective on DL games
- A boilerplate example game with a video, displaying sensor DL game design

After a problem elaboration, and a systematic literature review, learning goals were created as well as design ideas for DL games. Because of the chosen focus on sensors, both the goals and the design ideas were based on learning DL through games exploring sensors. The design went through an iterative process, including a co-design session with a game design expert, and was further explored through student and teacher interviews, as well as

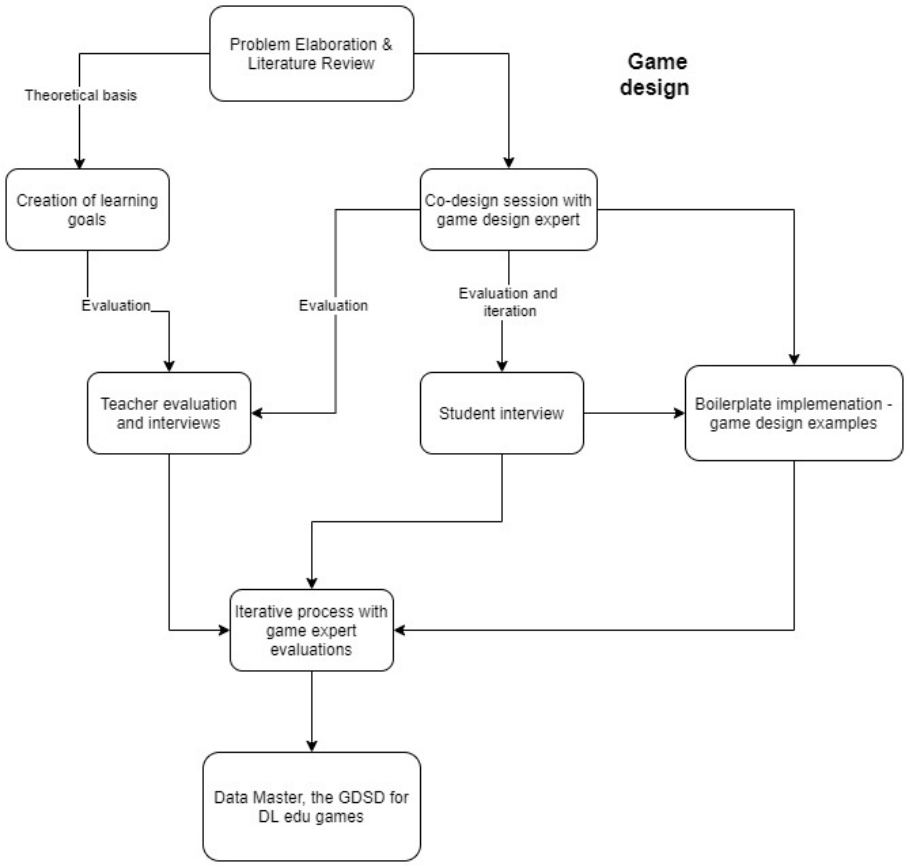


Figure 1.2: Outline of research process in this master thesis

some implementation. The learning goals were evaluated by teachers, a set of interviews which also explored the use of games in the classroom, from the teacher perspective. The findings were summarized in a GDSD, which was created through an iterative process, including feedback from various game designers. The GDSD titled Data Master is the design artifact and main product of this master thesis, combining contributions form an iterative game design process, with background research and findings through interviews. The document is intended to facilitate game designers in the creation of innovative DL games for secondary school education.

1.6 Outline of this Report

Chapter 2 elaborates on the growing importance of data, and the implications this has for education. The chapter also describes the untapped potential for educational games. This is done by incorporating observations from the literature on educational games. The chapter continues to describe ways of incorporating knowledge from the literature into the design of the game, as well as the learning goals for the game, and the activities surrounding the game. The chapter addresses choices done in the project, in relation to the problem.

Chapter 3 is a literature review that makes up the foundation on which the problem and methods in this project are built. In the review, various published, peer-reviewed sources are summarized and discussed to determine what is known about data literacy initiatives in education, with emphasis on projects that make use of games.

Chapter 4 describes the creation of learning goals set for the game design ideas explored in the project. The chapter involves an investigation into various sources upon which to base the learning goals.

Chapter 5 describes the game design process, which lay the foundation for the design ideas discussed in the GDSD, as well as the boilerplate implementation. The chapter describes an evaluation and co-design session with a game design expert from academia.

Chapter 6 describes evaluation done through a set of teacher interviews as well as a student interview at a lower secondary school (grades 8-10). An evaluation of learning goals, as well game design for classroom integration, was conducted.

Chapter 7 describes the iterative process of creating the GDSD titled Data Master. This involved an iterative process including expert feedback from game designers.

Chapter 8 is the GDSD, Data Master, which is the design artifact and final product of this master thesis. The document is included as a chapter, but should serve as a standalone document to facilitate the design of DL edu games.

Chapter 9 includes conclusions and reflection on the work.

1.7 Changes due to Corona Epidemic

When the project was initiated, the original plan was to design and develop a prototype for an educational game which was meant to teach DL. The early work of this report was

initially done was to develop this prototype, based on literature and interview feedback. The plan was to test the game with a group of students, as a final evaluation.

However due to the global Corona pandemic of spring 2020, this plan was altered. The main reason for the change was because doing interviews with students, teachers, or other experts was no longer possible. The shutting down of many societal functions, like closing down schools and universities, as well as an enforced quarantine made it impossible to test the game in a class. At this point in the process, interviews with experts, teachers, and students were completed (described in chapter 6). The interviews indicated that there was big potential for DL games, and similar educational games, which was also consistent with literature.

Building on the work done to create a game, the focus of the project became to explore and describe the space of design for of DL edu games. The final contribution of the project was the GDSD, the creation of which was based on the game design process. The experience gained during the design and development of the game was essential for creating Data Master. Gaining hands on experience working with DL educational games greatly contributed to understanding the need for a GDSD, and how it could be designed. Experience from the game design process was also useful for the process of creating the GDSD. The work put into the creation of the game was fully re-purposed for Data Master, and many of the discarded design ideas could also be included, because of the added broadness. Having a GDSD as a final product allowed the theoretical background, the interviews, and more of the game design process to be described in the final product, compared to a game as a final product.

Chapter 2

Problem Elaboration

Quick summary of chapter.

2.1 The Importance of Data Literacy (DL)

Note: This project focuses primarily on environmental sensor data. Though the topic of personal data, as it relates to issues of privacy, surveillance, security, and advertising is important, the project about which this report is written, focuses only on learning to use sensor data (see section 1.3).

2.1.1 The Need to Learn Data

The amount of data available is growing, and so is the potential for its use. Smart gadgets such as phones, watches, pads, and other electronics are equipped with a multitude of sensors that collect data. Software companies like Microsoft, Google, and Apple, collect billions of data points every day from their users. A DOMO info-graphic titled *Data Never Sleeps 7.0* from 2019 summarizes the data volume thus: ”In 2020, there will be 40x more bytes of data than there are stars in the observable universe” DOMO (2020). Figure 2.1, an excerpt from this info-graphic, shows the growth of the internet population years 2012-2018, which is not only immense but also accelerating. If this continues, the whole planet will soon be connected to the internet, creating and using data. Being able to understand and use data is therefore a vital skill in today’s society, and its importance is undoubtedly

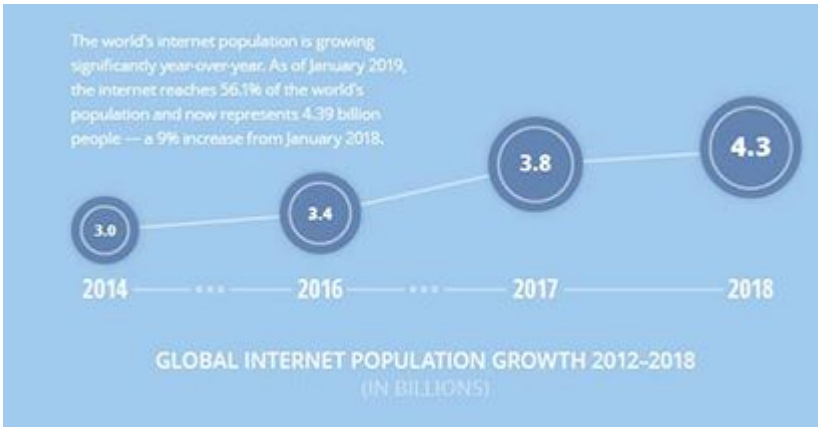


Figure 2.1: The growth of the internet 2012-2018 — DOMO 2019

growing.

A Tableu report titled *The State of Data Education in 2016* appraises the importance of data skills, stating: ”Already, data skills are a basic proficiency required at work. In the near future, all jobs will touch data in some way.” The report also cites an interview with Raphael Papa, principle at UCBR, who describes data science and analytics programs as “one of the most significant additions to the portfolio of graduate degrees in U.S. higher education in the past 50 years – perhaps since the advent of computer science degrees.” In the report, they delve into how data is handled in higher education, and specifically how the educational landscape is adapting to meet the market's rapidly increasing demand for analytics skills. The report shows that new programs are appearing to accommodate the increasing amount of data analytics jobs. However the report only focuses on higher education, there is no mention of high-school, or lower level education.

Koltay (2017) backs this up by stating that ”Its important characteristic is a close connection and similarity to information literacy.”, and also argues ”Data literacy is vital for researchers who need to become data literate science workers and also for (potential) data management professionals.” Koltay (2017) We understand from this that data literacy and its related literacies are important for researchers and statisticians, who are higher levels of education, however there is more to be said for the lower levels of education. Where will students get a foundational understanding of data to build upon when learning about data in university?

EU Digital Competence Framework

The EU European Commission developed a digital competence framework, written by Carretero et al. (2017) which member nations are expected to use as a benchmark for their citizens IT competence. It outlines some important areas for understanding digital technology, and establishes clear requirements for various aspects of digital literacy. One of the main areas of this framework is about data and information literacy, fields which often blend over into one another. The framework includes various levels for each area of competence, and it is of obvious benefit to a society to increase its population's digital competence, indicated by reaching the higher level competence goals defined by the framework. The increasing focus, and raised expectations for digital literacy is increasing, and with it the need for DL education.

2.1.2 The State of Norwegian Data Education

Schools are in a process of adopting digital tools. Digitalizing the classroom has been a goal for years, as supported by the introduction of school PCs - in high school (videregående skole) every student gets their own laptop. The introduction of an elective that aims to teach programming - a fundamental computer science skill - is perhaps the clearest example of a growing focus on computer science in schools. Magnussen and Holst (2018) explored developing an educational game for teaching programming.

As data becomes an increasingly important topic for the modern world, some focus has been given to DL in secondary school. However there are many challenges with adapting to the need for data education, making this a slow process. One of the central challenges of introducing new topics is teaching capacity. Computer science, the topic under which DL falls, is such a new field that few teachers have the education to teach it. Therefore the demand for effective teaching tools for core computer skills such as data literacy is growing.

2.1.3 Summary

To summarize: Data has been growing in importance as the usage of computer technology keeps increasing. Schools are becoming increasingly digitalized and digital tools such as games are being adopted. A data literacy game could therefore help schools improve their DL education. The next section explores this option.

2.2 Using Games in Education

2.2.1 The Importance of Games

”Contemporary developments in gaming, particularly interactive stories, digital authoring tools, and collaborative worlds, suggest powerful new opportunities for educational media” Squire (2003). Kurt Squire wrote this about the potential of games in education, in 2003. In his paper simply titled *Video Games in Education*, he argues that games as a medium have largely been ignored by educators. Since 2003, both games in education, and the medium as a whole has grown significantly. This section describes some of what is known about educational games, to determine how the game should be used in education.

Video games have, over the last three decades, exploded in popularity, and in 2018 it fell just bellow 135$ billion in total sales. The money spent on games has been growing every year, with no indication of stopping. Business Insider report that: ”according to Microsoft, there are more than two billion gamers around the world ... in 2022, experts forecast the gaming industry will produce $196 billion in revenue”Webb (2019).

2.2.2 Educational Games as a Research Topic

Along with both the staggering usage of video games in the world, and the growth of the internet (see figure 2.1), educational games have become an important research topic. Some games have been made with the goal of teaching data literacy, approaching the topic from various angles. Their focus has ranged from personal data to active citizenship.

Though for some, the idea of an educational game is still new, games are being used more and more, and their potential for use in education is promising. Zirawaga (2017) writes *”Gaming in education may be viewed as an interference to learning but its role in education is to increase students’ motivation and engagement, to enhance visual skills, to improve students’ interaction and collaboration abilities with their peers and to enable them to apply gaming values in a real-world situation”*. They go on to argue that games can be used to simplify educational practices, increase student engagement and motivation, and provide valuable learning. However they also specify that the use of technology - such as games - is only helpful if used correctly within the classroom.

Though researchers have only just begun to explore the topic of educational games, many important findings have already demonstrated their importance. Games are an interactive and adaptable medium, which are important traits for education. Games may

be able to significantly contribute to the education system. Mayer (2016) states ”Media comparison research shows that games are more effective than conventional media for science learning”. This indicates that there significant untapped potential in educational video games. He goes on to discuss specific advantages of games in educations, stating: ”Policy implications are to use games for targeted learning objectives, align games with classroom activities...”. Games as a medium have the ability to meet specific educational needs, such as the relatively new topics surrounding data and IT, for which teachers do no have training.

2.3 Proposed Solution: Game Design Space Document (GDSD)

This project aims to facilitate the creation of educational games about data literacy, by providing developers with a research based Game Design Space Document (GDSD), detailing various opportunities and approaches related to educational games teaching sensor data literacy.

The project is also done keeping in mind the new plan for education mandated by the Norwegian government, that emphasizes sustainability in education. ”Sustainable development as cross-disciplinary theme in school should facilitate student understanding of foundational dilemmas and developmental traits in society, as well as how these can be handled.”(original quote in Norwegian translated by the author of this report). Data Master will thus have a theme inspired by relevant sustainability challenges, thus further justifying its relevance in school curricula. Excerpts from the foundational goals (Overordnet del) of the 2020 Norwegian learning goals can be found in appendix A.2.

2.3.1 Game design goals for Data Master

The game-design process which produced the designs presented in data masters had two goals. The first goal was that the game design should help teach players DL. One proposed solution was to expose players to realistic sensors in a virtual environment. Further, a Data Master game should help players understand the utility of such sensors, and how to use them. Solving problems by using sensors lets players get experience in sensor driven problem solving, and the goal of the project is that this experience translates to real life counterparts. The design ideas should primarily aim for an increase in DL.

The other primary goal for Data Master is that the game design should be engaging. The game design was done with engagement as a fundamental goal. To do this, the design should aim to be fun, interesting, and/or engaging. Not only does this increase learning, but it also helps students cope with subject matter that they might find challenging or theoretical.

2.3.2 Design of Setting - Sustainability

There are many potential settings for games that teaches data to students in school – data is being collected everywhere. Chapter 5 will describe the game design process involved in the creation of the GDSD, Data Master. As the this project's solution was proposed (originally a game – see section 1.7), one of the main goals was design a game setting which could promote sustainability. The core educational themes in the 2020 Norwegian educational values describes sustainability as a pillar (see appendix A.2). Design ideas for the Data Master GDSD centered around solving problems of sustainability, by collecting relevant data. Exploration was done for collecting data in both a virtual and/or a physical environment.

2.3.3 Playfulness

In their research project Magnussen and Holst (2018) aimed to discover which game elements appeal to lower secondary school students. The findings were later used in their development of a game for teaching programming Holst and Magnussen (2019). One central finding was that the use of playfulness was important for educational games aimed at this demographic. "The playful setting of a task can help players understand problems better" (p13). Addressing playfulness is therefore important when creating educational games.

2.3.4 Design Artefacts

"*This paper introduces the concept of design artefacts as a generic term for the outcomes of research in design and use of computer artefacts, e.g. theories, methods compilers, editors, debuggers, and case tools. The concept of design artefacts entails concerns for design and use, and the relation to research and method development*" . So wrote Olav Bertelsen (2000), in his paper on Design Artefacts. In this paper he argues that in fields where design oriented knowledge is the focus, using only traditional epistemology is inadequate.

He further suggests the concept of design artefacts as a foundation for an epistemology that is more pragmatically oriented. ”Because computer artefacts eventually are to be used in the real world, research in these fields tends to emphasise relevance over scientific rigour” Bertelsen (2000). With this, Bertelsen argues that when dealing with scientific knowledge about the design and implementation of something which is to be used in the real world, one should use methods that reflect these goals. This report specifically uses principles in design-science methodology, because as Bertelsen observes, such methods are founded better in the design-oriented, pragmatic epistemology.

2.4 Psychology of Game Learning

This section looks at some of the literature for game learning. Understanding the psychological perspective will be an advantage for designing games which succeed at teaching. The research will be a foundation for creating and selecting game design ideas to describe in Data Master.

Mayer 2019

Richard Mayer (2019) elaborates on the psychological implications of learning through games, in his annual review of the learning potential of games. According to Mayer, when a student plays an educational game, their processing capacity gets allocated among three categories, the first being extraneous processing. This processing does not serve the instructional objective and should be avoided as much as possible. A game which has distracting features or simply poor instructional design will see its players waste their processing capacity, which could be used to learn Mayer (2019). Avoiding such extraneous features is therefore a vital goal of designing educational games, and any game made to educate should be play-tested in multiple iterations, if possible, to reduce the amount of extraneous processing done by the players.

The other two kinds of processing discussed by Mayer are essential and generative processing. They involve respectively trying to represent the material (more complex material requires more processing), and trying to make sense of the material by exerting effort. Mayer goes on to state that ”Computer games may be particularly helpful in fostering generative processing, but are susceptible to creating extraneous processing.” Focus in the design process of this project (described in chapter 5) will therefore be on minimizing extraneous processing, while maintaining generative processing. Essential processing should also go as smoothly as possible, and the game design will thus guide this, as suggested by

Mayer (2019).

Mayer 2016

In 2016, Mayer discusses other findings of games in education, in the publication *What Should Be the Role of Computer Games in Education?*. He summarizes that the most promising features to be used when teaching with games are: ”conversational language, put words in spoken form, add prompts to explain, add advice or explanations, and add relevant pregame activities” Mayer (2016). An observation about Mayer’s listed features is that they all involve an element of accessibility. Accessibility features in games are features designed to make the game approachable and easy to play. These can include tips that make it easier for people who do not play games often, or are unfamiliar with computers in general, but can also include features for people with color blindness or other disabilities. There are several reasons why this might be extra important in an educational setting, as opposed to a commercial one. The first is that students have highly varied interests, and thus many of them are likely to not be very familiar with games in general. Making it easier for them to understand how to play the game reduces extraneous processing, and lets them focus on the learning the game provides. The features Mayer lists all contribute to making the game easier to understand, which minimizes extraneous processing, and some of them, like pregame activities and explanatory prompts also encourage further reflection. Making students reflect on learning material is an important step in the learning process, and facilitating reflection in the game’s design should therefore be prioritized.

2.5 Definitions — Data-Related Subjects

2.5.1 Definition of Data Science

Donoho (2017) describes the origin of the term ’Data Science’, as coined by Bill Cleveland, in an effort where he and others, independently, called for the field to be separated from traditional statistics. Donoho further establishes that ”The now-contemplated field of Data Science amounts to a superset of the fields of statistics and machine learning which adds some technology for ’scaling up’ to ’big data’.” Donoho (2017)

In their 2017 article, Maneth and Poulovassilis use this definition: ”Data Science refers to an emerging area of work concerned with the collection, preparation, analysis, visualization, management, and preservation of large collections of information.” Maneth and Poulovassilis (2017)

For the project about which this report is written, it is most appropriate to use the term 'data science' as it relates to "the understanding, analysis, and visualization of data". Focusing on more fundamental concepts such as understanding and utilizing data should be the primary focus, as the target for this project is secondary school students.

2.5.2 Data Literacy

Learning about data has roots in the fields of mathematics, computer science, statistics, data mining, and information visualization. Historically, definitions have arisen from these fields, and been extensions on information and statistical literacy. Schield (2004) wrote about data literacy that "The evaluation of information is a key element in information literacy, statistical literacy and data literacy. As such, all three literacies are inter-related". However in recent years, the topic of data is emerging as transcendent of these foundations, and so the definition of data literacy must be updated.

Contemporary definitions of data literacy involve a hierarchy of four central competencies. These competencies are: identifying, understanding, operating on, and using data Bhargava and Ignazio (2015). In another article, Koltay (2015) describes the role of data literacy as including such activities as curating, citing, and managing data, and goes on to argue that "It can be concluded that there is a need for data literacy and it is advantageous to have a unified terminology" Koltay (2015).

An important contribution to this unified definition of data literacy is the article "Creating an Understanding of Data Literacy for a Data-driven Society" by Wolf et al. In this paper the five authors analyze existing interpretations and propose an inquiry-based definition of data literacy, to function as a common foundation for teaching and learning DL skills. In their concluding definition, they focus on the ability to ask and answer real-world questions. This is based on core practical and creative skills: to select, clean, analyse, visualize, critique, and interpret data, as well as being able to communicate stories from data, or use data as part of a design process Wolff et al. (2017). The article is covered further in the literature review 3.1. This is a thorough definition that unifies different approaches to create a broad fundamental definition. When designing the Data Master document, the definition of DL was derived primarily from Wolf et al.'s article, with the goal that games created based on the document should see improvement in the data literacy related activities discussed. Figure 2.2 illustrates the use of data literacy in context of real world ethics and problem solving, as described by Wolff et al.

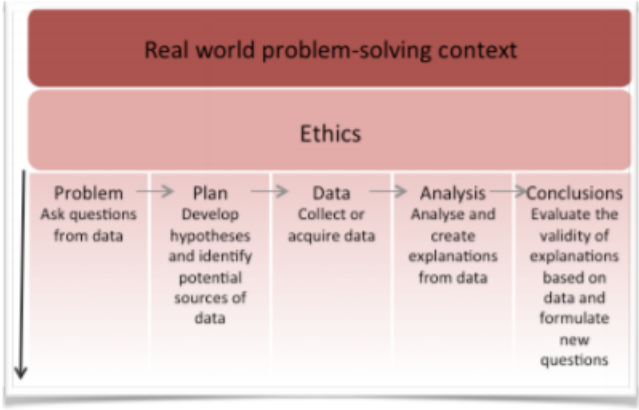


Figure 2.2: The space of data literacy skills - Wolff et al.

2.5.3 Definition of Data

A point of data, or a datum, refers to a single unit of information, and is used to describe the quality or quantity of an object or a phenomenon. It is measured, collected, and analyzed to gain knowledge. In this report, sensor data is in focus. Sensor data is data collected from a sensor that measures some quality or quantity, which will in this case be from the local environment.

Chapter 3

Literature Review

This literature review is an exploration of what is known about data literacy (DL) initiatives, with emphasis on those that use games. The review should reveal how games have been used to teach DL. Educational games has been a topic of interest during the last decade, and a multitude of papers have been written exploring the efficacy of games as educational tools. DL is increasingly important, but being a new topic, teachers lack the training to teach it. One of the topics researches have focused on has therefore been educational games as tools to teach DL.

This literature review is a compilation of central research on the topic of game based DL education. The review has three main purposes for this project:

1. Create a foundation of knowledge on which to base theory, methods, and practices of the DL education research conducted in this project
2. To learn what elements of DL games designers have used successfully in the past, and which not, to inform the design process of Data Master
3. To understand the challenges associated with DL initiatives, to avoid pitfalls and be equipped to tackle obstacles as they appear

There are challenges with teaching new material using educational games in and out of the classroom. This literature review investigates solutions to common challenges with data literacy educational games. Data Master should be designed with any found solutions in mind, equipping it to handle these challenges. Discovering the common problems and

solutions will be done by reviewing what is known about DL initiatives that use digital tools. Focus for the analysis should be on understanding the methods and constraints of creating DL games.

3.1 Literature Search

This section describes the literature searching process. It describes the search query, databases used, and search results.

3.1.1 Search Query

Before literature searches were conducted, the search query was planned, to calibrate the yield of the search to be small number of highly relevant papers. An iterative process on the search query was initiated, queries being created from keywords found in the literature surrounding the most important concepts for the project. Central keywords were found by analyzing the problem statement, and taking into account the research questions. The keywords and phrases selected were: **data literacy, games, education**. The queries were combined using **OR** statements, to combine all the results in one search. Synonyms or equivalent phrasings were also used to ensure the inclusion of projects that might be highly relevant while using slightly different vocabulary.

The query used was:

game **AND** (”teaching data literacy” **OR** ”learning data literacy” **OR** ”data literacy initiative” **OR** ”data literacy education”)

Note: The query was adapted to each database, based on their particular configurations. Different databases use different symbols, for instance ACM uses the + sign for required terms, so adding these symbols was done to make the different databases search the same way.

This query covers material that involves the word game, as well as various formulations of teaching DL, either framed as teaching, as learning, or as an initiative to increase DL. Quotation marks were used to only include certain exact phrasings, which filters out many false positives. This search should produce projects that involve games that teach DL.

3.1.2 Databases Used

The search was conducted using six relevant databases to the field of computer science. Among them was Google Scholar, a more general database. This was included to increase thoroughness, reducing the chance that important material from another field would be missed. These are the databases used for the search: ACM [1], IEEE [2], Web of Knowledge [3], Science Direct [4], Scopus [5], and Google Scholar [6].

3.1.3 Search Results

[THIS] table shows an overview of the search results:

Literature Search	
Database	**Total Results**
ACM	30
IEEE	29
Web of Knowledge	1
Science Direct	2
Scopus	1
Google Scholar	72

Previous Searches

Some literature was also uncovered before the literature review started. These sources were found in relevance work for the project as a whole. These searches can be seen as an exploratory preamble to the literature review, and for purposes of documentation and rigor, they are described here. To find this literature Google Scholar was used. These are the searches done in Google Scholar previous to this literature review, that yielded useful sources as a result:

- ”teaching data literacy” games
- games ”data literacy” education

[1] https://dl.acm.org/
[2] https://ieeexplore.ieee.org0
[3] https://apps.webofknowledge.com/
[4] https://www.sciencedirect.com/
[5] https://www.scopus.com
[6] https://scholar.google.com/

Other searches were done as well that were found to be less valuable, and were thus not included. Here are some examples of these searches:

- games data literacy
- educational games

3.1.4 Broad Search

Before completing the selection of literature, an additional search was made. This was intended to give a wider set of results. Skimming through this list to select additional material was done, to add thoroughness to the search, and to ensure that the resulting set of literature was complete.

The query used for this search was:

(kid **OR** child **OR** student **OR** pupil) **AND** ”data literacy” **AND** sensors **AND** (education **OR** classroom **OR** school **OR** learning)

Not all results of this search were examined, but among the most relevant results, two additional articles were added to the set of literature for review.

In addition to this, the cited works of the literature was also examined, to look for works cited by multiple sources. These influential works can often be highly relevant to the literature, and should thus be included along with the search results.

3.2 Selection of literature

Thoroughly reading every result of a literature search is a waste of time, as only a fraction of the publications will be relevant to the topic at hand. Thus, having an effective selection process for which articles to read is important. Reading the title and abstract of a publication gives a good indication of whether a publication is worth further investigating or not. Publications eligible for considerations must therefore have an abstract, be published in a peer-reviewed journal, an international conference, or be a chapter of a book. For this literature review only publications written in English or Norwegian was considered. In addition to this, a small set of requirements was made for publications to be selected into the review.

3.2.1 Selection requirements

- The publication must focus on data literacy, either directly or indirectly. This may include publications on information literacy.
- The publication must involve education or learning.
- The publication must involve games, or some similar kind of digital medium.

At the end of the selection process, **12** works were chosen to be part of the literature review. Table 3.1 shows the the selected works, appearing by title, and ordered first to last by publishing year.

Literature for Review		
Ref.	**Title**	**Year**
Wong (2009)	Kids' Survey Network: Teaching Data Literacy with Multiplayer Online Games	2009
Vahey et al. (2012)	A cross-disciplinary approach to teaching data literacy and proportionality	2012
Deahl (2014)	Better the Data You Know: Developing Youth Data Literacy in Schools and Informal Learning Environments	2014
Williams et al. (2014)	City Digits: Local Lotto: Developing Youth Data Literacy by Investigating the Lottery	2014
Wolff et al. (2015)	Urban data games: Creating smart citizens for smart cities	2015
Wolff and Kortuem (2015)	Visualising energy: teaching data literacy in schools	2015
Bhargava and Ignazio (2015)	Designing Tools and Activities for Data Literacy Learners	2015
Bhargava et al. (2016)	Data Murals: Using the Arts to Build Data Literacy	2016
Guo and Goh (2016)	From storyboard to software: User evaluation of an information literacy game	2016
Wolff et al. (2017)	Creating an understanding of data literacy for a data-driven society	2017
Gäbler et al. (2019)	Diagram safari: A visualization literacy game for young children	2019
Grillenberger and Romeike (2019)	About Classes and Trees: Introducing Secondary School Students to Aspects of Data Mining	2019

Table 3.1: Reviewed Literature

3.3 Reading and Summarizing the Literature

This section summarizes the works selected from the search. Following these summaries there will be a discussion of the material and how it can be used as a fundament for the project. The articles in this section will be presented in chronological order, based on publishing year. This order is useful as some authors build on others, or on their own previous works.

3.3.1 Kids' Survey Network: Teaching Data Literacy with Multiplayer Online Games

Christopher Wong contrasts the increasing technological prowess of modern society with the observation that the rate of data literacy among many is inadequate. He focuses on the importance of data as it pertains to statistics, but also how it is interrelated with IT. His report describes a large project called *Kids' Survey Network*, which uses games to teach DL to middle school students. Wong and colleagues' project focuses primarily on statistical literacy, and visualization, as opposed to focusing on the use of sensor data as is done in this project. Other projects might focus on personal data; any of these foci are valid when discussing DL, but it should always be clearly denoted in which category any project fits. These different approaches all provide contributions to the greater field of knowledge which is DL — and in this case how it relates to education.

Further Google Scholar searches on "Kids' Survey Network" yielded no new results, but revealed that other DL researchers had cited the project.

3.3.2 A cross-disciplinary approach to teaching data literacy and proportionality

In this article Vahey, Rafanan, Patton, and Stanford investigate a cross-disciplinary approach to teaching DL, named the Thinking With Data project. They define data literacy as the ability to make sense of the quantitative data in society, and argue that mathematics are vital in giving students the ability to understand, manipulate and argue using quantitative data. In this exploratory study, they create cross-disciplinary DL education materials, and investigate their effectiveness.

In their attempt to find a theoretically sound approach to providing cross-disciplinary DL instruction, Vahey et al. discuss the benefits of using real-world data across the curriculum - shown to be praticularly feasable in combination with understanding proportional measures. This way, learning DL can be coupled with curricular activities, and easily integrates into current curriculums.

3.3.3 Better the Data You Know: Developing Youth Data Literacy in Schools and Informal Learning Environments

Another piece of literature on DL education this is Erica Deahl 2014 paper, an MS paper in comparative media. This paper has clear relevance to the topic of at hand in that one of its stated aims is to provide a new definition for DL to adapt to a changing contemporary technological landscape. Deahl also analyzes two data literacy initiatives which enable youths to learn to tackle challenges by using data. Deahl describes some challenges that come up during DL initiatives, and from her analysis outline three design principles for researchers.

In her thesis, Deahl focuses on how data education can enable young people to better understand ethical challenges related to data, and uses as example corporate personal data collection and utilization. Deahl also investigates how data is supported in schools, and what categorizes successful DL initiatives. Her main focus is to change some of the societal data management from a top-down to a bottom-up structure, through DL initiatives. Though her focus is on personal data and not sensor data, the motivation of her project is well articulated, which makes it relevant for this project. Her focus on education parallels this project, and her findings should thus be taken into account.

3.3.4 City Digits: Local Lotto: Developing Youth Data Literacy by Investigating the Lottery

Williams, Deahl, Rubel, and Lim investigate how the essential skill of data literacy in a data driven society can be supported in high schools, with a web application called City Digits: Local Lotto. The application allowed students to perform qualitative data collection and quantitative analysis, further enabling students to make data driven evaluations.

This web application, though not strictly a game, has many similarities with DL education games, and studying the project should therefore be useful for Data Master. The study describes how students are better able to understand and contextualize data when

they have participated in its collection. It could therefore be advantageous to have players of Data Master collect data, instead of only analyzing it.

3.3.5 Urban Data Games: Creating smart citizens for smart cities

Wolff, Kortuem, and Cavero argue that contemporary data educational practices are too narrow, using only small data sets and basic charts and graphs, which is inadequate for the increasing data challenges of daily life. In this article they describe a bottom-up approach to smart cities, which has citizens actively contributing by using data. This requires higher rates of DL, and observe shortcomings in current education to provide this needed understanding. The paper proposes an approach to teach DL by using Urban Data Games (UDG), supported by training data and other resources. They conclude that these data games allow learning around a specific task, and are supported by larger data sets.

This project is useful to study for Data Master because it involves the evaluation of various different DL games. The focus is on urban data, which is conceptually close to the environmental focus in Data Master as both aim to impact local environment through data. The emphasis on sustainability in both projects make UDG worth studying. In the article, Wolff et al. describe playfulness as an important goal for the games' educational efficacy. They focus on motivating and supporting players to both learn about and then apply data skills for real data sets. In the article they describe the principles in a successful UDG as "narrative, game-based learning, inquiry, collaborative learning and challenge", and through the project more specific requirements were developed based on these principles. Examples of these specific requirements include clear indications of the particular data skills needed to complete a task.

3.3.6 Visualising energy: teaching data literacy in schools

Wolff and Kortuem observe the increasing complexity of data sets, which demands higher levels of DL from citizens. As in their other project, *Urban Data Games*, they argue that contemporary approaches to data education are too narrow. In the paper, Wolff and Kortuem argue that data should be taught in schools, and investigate getting students to engage with complex data sets.

This paper is of value to Data Master first in its advocacy for DL education, challenging the current lack of emphasis of the subject in schools. It also discusses ways students can engage with data and how this can be useful for their DL development. Students in the

project are tasked with creating visualizations, which though not specifically a game, is a problem solving way of tackling data. The small project concludes that though some students can develop deeper understanding of data, prompting and support is generally needed to get them to more advanced ways of thinking with data. Building on this, an educational game could solve this need for further support and prompting by building these features in. Video games are also effective tools at giving players the right amount of challenge for their level. Thus a well designed educational game could be helpful both for the students who struggle with the tasks, and for the students who take easily to the material, by appropriately challenging them.

3.3.7 Designing Tools and Activities for Data Literacy Learners

This short paper by Bhargava and D'Ignazio (2015) also focuses on DL education. However data literacy is used more broadly in this instance. Instead of focusing mainly on personal data, a historical understanding of data science is first applied, exploring its roots in statistics and IT. The paper both sets principles of designing DL tools, and then tests these principles by making such a design and analyzing it as a case study. This is relevant to the project in that it describes guidelines for designing DL tools, and provides an example of their use. Building on this paper is therefore important, to make use of their findings.

In this article the authors provide a definition for DL based on the history of the term and contemporary practices. Including this definition into the sources to draw from will be useful when defining DL in this project. Comparing different researchers' definitions provides an idea of what to focus on when working with DL. Bhargava and D'Ignazio focus on four different skills in their definition. They are reading, working, analyzing and arguing. Someone who is literate in all these areas can understand, acquire, and aggregate with data, and use this to support an argument. From this definition, and from the authors' focus on data science, it appears that this definition primarily applies to scientists, or students of higher education. This is in contrast with Deahl, who focuses on middle school children, who generally approach data at a different level.

3.3.8 Data Murals: Using the Arts to Build Data Literacy

In this article, E. and R. Bhargava, Kadouaki, Castro, and D'Ignazio investigate the use of arts as a means to build data literacy. The article showcases an example of building data literacy through using visual arts activities. As a result of the project, data literacy among

students was increased, and continued interest was sustained by the school.

One of the central conclusions from reading this article is that the arts is an underutilized arena for exploring and learning data literacy. The project was successful in increasing participants' DL, while focusing on painting, and set in a school which allows students to pursue creative arts. One might easily draw the conclusion that more mathematical, and rationally oriented students would be the ones to take most easily to DL, however this study suggests that there is also powerful opportunities for students who are more creative or interested in arts or self expression. Building on this, an interesting case for the use of games to teach DL can be made. A video game can be both a logical system with intellectual challenges for thinking players, but also a piece of art, expressing parts of human experience. Many articles about video games as art have been written, among them Smuts (2005) article simply titled "Are Videogames Art?" where he makes the case that they areSmuts (2005). Bhargava et al. use the data mural project to show that it is not only the intellectually challenging part of games that could work for teaching DL, but also the more artistic part.

3.3.9 From storyboard to software: User evaluation of an information literacy game

In this project, Guo and Goh employ a user-centered design approach to create an information literacy (IL) game for education. The authors argue that though games are a potent medium to engage and motivate players, educational games frequently fail as users are not included in the design process. The game was evaluated using pedagogical heuristics, and implications for the design of IL games.

Guo and Goh focus on information literacy, and not data literacy, which they define as the ability to efficiently seek, locate, and navigate information, allowing students to synthesize information. Though not strictly about DL, this related field still has valuable lessons for Data Master. The method of using an educational game, and further using the user-centered approach, is highly relevant; studying this project gives valuable background to the method and approach of the design phase for Data Master (see section 5). Specifically the use of semi-structured interviews to involve users in the design process could be highly useful, gaining valuable feedback, but also possibly some powerful ideas for further development.

Another interesting method from Guo and Goh's project is the use of self-assessment tools integrated into the game. A challenge of game-based learning is that players might

learn the lessons intuitively but struggle to draw them out of the game context Guo and Goh (2016). By involving self-assessment, in the form of questions about the learning material, students are compelled to reflect on what they have learned. This approach could also be used in Data Master, and will be considered. The results Guo and Goh document in their article also provide a useful background for this method and its results.

3.3.10 Creating an understanding of data literacy for a data-driven society

In this article, Wolff, Gooch, Montaner, Rashid, and Kortuem address the growing importance of data in society. They argue that citizens need to acquire DL education. In the article they focus on defining the DL, as it pertains to the needs of citizens. By surveying existing approaches in schools they propose a definition of DL which focuses on using data to understand real world phenomena. In the article they develop a general, future oriented definition of DL, which is not oriented around a specific scenario, by identifying commonalities between various definitions. By this, the authors want to achieve a common foundation for teaching and learning DL skills.

Data Master was created with the goal facilitating the development of games that teach DL. Gaining a full understanding of what DL is, and the associated needs of society is important. Though this article does not provide specific examples of how games can be used to teach DL, it does address fundamental theoretical questions on the topic of DL education. Definitions and concepts in this project should therefore build on what Wolff et al. describe.

Based on their work with DL definitions, Wolff et al. also describe four types of data literate citizens. This list includes communicators, readers, makers, and scientists. Though not exhaustive, this list is important to categorize different kinds of DL needs. However Data Master focuses specifically of one aspect of DL, which is related to sensors, as described in section 1.3.

3.3.11 Diagram safari: A visualization literacy game for young children

Upon the premise that DL has become a critical skill in information-driven 21st century society, Gäbler et al. introduce an educational game to foster DL among 9-11 year olds. They report on the iterative design process and describe an early evaluation which shows

promise. The project focuses primarily on the ability to visualize data, and tangentially to understand, and analyze it.

This project is relevant to Data Master because it is an example of a DL educational game for children. Though a different part of DL is focused on, the subject matter is still close enough that there will be plenty of overlap between the projects, and thus there may be valuable lessons to investigate. The documentation of the design process and consecutive preliminary testing could also be highly instructive for the exploratory design process of Data Master. For instance, Gäbler et al. used an iterative design approach, from idea to a low-fidelity, and a high-fidelity prototype, before doing an evaluation with students. The authors also emphasize the importance of finding an appropriate level of challenge, asserting that this will motivate players.

3.3.12 About Classes and Trees: Introducing Secondary School Students to Aspects of Data Mining

In an early author draft, Grillenberger and Romeike investigate data analysis from a secondary perspective, arguing that DL skills are essential not only for students but for everyday life as well. Based on theoretical and didactic foundations they describe a teaching concept which aims to foster basic data competence. The article also discusses the specifics of methods and tools used along with the concept, and review the positive results from an evaluation with ninth-grade students.

This article is highly relevant to any project using digital tools to teach DL, as it outlines a DL competency model which is well founded in CS education research. Grillenberger and Romeike also show promising early results with their use of the model. This model was therefore taken into consideration when evaluating the design process for Data Master.

3.4 Analysis and Relevance

When analysing the literature to be used in this project, the focus was on methods and challenges of creating DL games, and the research surrounding these processes. Understanding the results of other researchers was important in this effort.

When reviewing the challenges with DL initiatives as they appear in the literature, the main foundation for the analysis comes from Deahl (2014), which has the specific focus

of ”analysing the challenges facing DL initiatives”. In this article Deahl analyses the literature at the time surrounding DL initiatives, which range ”from the constraints for the public school environment, to the challenges of reaching diverse audiences and supporting open-ended learning.” This analysis will be used as a fundament for understanding key design challenges which may be encountered during the creation of Data Master.

This literature review has revealed that there are studies about games that teach data literacy in education. These data literacy education games are: Kids' Survey Network as described by Wong Wong (2009), a large project through which a suit of educational games were made, Diagram Safari by Gäbler et al., which focused on visualization and statistical literacy,

There are other educational data literacy initiatives as well, two of which described by Deahl Deahl (2014).

Results

We see many examples of positive results for teaching data literacy in innovative ways, and several games were successful in improving players' data literacy. This speaks to the feasibility of creating data literacy games. Through this review games are found to be a viable option for teaching DL, which is promising for the exploration of the design space in following chapters.

Definitions of Data literacy

This literature has also provided several examples of scholarly definitions of data literacy. It can be observed that data literacy researchers use definitions that are in part based on their target group of subjects, e.g. more technical definitions apply to the data literacy of higher levels of education. Similarly, the various areas of focus, e.g. personal data and privacy, sensor data, statistics, or visualisation, provide a difference of approach and have some unique challenges associated with them. Comparing this gives a more broad foundation on which to base data literacy work. The work of Wolff (2017) et al. focus on building a more solid definition of data literacy as it applies to education. Wolff et al. (2017)

Relevance to Curricula

Veha et al. combine learning data literacy with the mathematics curriculum, focusing on the creation of proportional measures, allowing students a tool to understand mathematics

and data together. This shows that using data to solve problems that exist in the curriculum not only increases students' data literacy, but could also be a good way of teaching the normal curriculum as well. When designing data literacy educational tools, efforts should thus be made to introduce relevant problems to student curriculums, allowing teachers to kill two birds with one stone, teaching their usual topics while simultaneously teaching data literacy. Wolff et al. (2017) cite a paper which suggests that an effective approach is to teach data literacy cross-curricularly, as multiple subjects like math, science, geography, as well as the humanities have relevant opportunities to engage with the topic Vahey et al. (2006). It is clear that to make the literacy game an effective tool in education, it should be relevant for multiple subjects. This also supports diffusion of the game, as more teachers may find opportunity to use it in their classes with a broader range of relevance.

Iterative Process

Gäbler et al. use an iterative design process, and show promising early results with their data literacy game. Their work shows the success of using an iterative approach. Using an iterative structure was chosen for the design processes of Data Master.

Playfulness

From this review, some preliminary conclusions on what makes an effective data literacy game can be drawn. For instance, playfulness is repeated as a compelling aspect of these educational games, which is also consistent with other literature on educational games Magnussen and Holst (2018). Eliciting playfulness will thus be one of the goals of the design/development process for the project.

Visualization

Another observation drawn from the literature is the focus on understanding data through visualization. Abstract ideas like data can be hard to grasp for young students, so engaging visually with the topic is useful in this regard. Data Master should thus involve visualization, and engage students visually when possible. Integrating these aspects in the learning goals of the game should also be considered, and enabling support for them in the hardware is crucial.

Chapter 4

Learning goals

In this chapter, learning goals will be discussed, for games that teach data literacy (DL), which will be useful for defining what educational games should strive to teach in Data Master. To make the learning goals relevant to Norwegian school curricula, state mandated educational goals (kompetansemål) will be considered. There are also various other sources that are relevant to consider when determining the learning goals, such as the *EU Digital Competence Goals*, as well as data education on higher levels, such as data science curricula in universities.

After a description of the background, the learning goals for the game will be listed. Following this the learning goals will be discussed, with an explanation of the reasoning behind each goal, and how it relates to the background and the problem statement of the project. The learning goals go on to be evaluated by teachers; the process is described in chapter 6.

4.1 Background for learning goals

For the goals to be relevant to the GDSD, their specification is based upon several authoritative sources. The first is the EU Digital Competence Framework, *DigComp2.1*, which has clearly defined objectives for data literacy and other IT competencies Carretero et al. (2017). Another important factor when specifying learning objectives is taking into account prescribed learning objectives for secondary school. Following these, however, is not necessarily a priority for learning data science, as data is not altogether decisively cov-

ered in today's curricula. In the motivation1.1 section of this report, the case is made for the importance of understanding data science in secondary school education. The curricula's learning requirements will therefore be useful primarily for ensuring that the GDSD is relevant for use in education.

4.1.1 EU Digital Competence Goals

Competence area 1: Information and data literacy

- 1.1 Browsing, searching, filtering data, information and digital content
- 1.2 Evaluating data, information and digital content
- 1.3 Managing data, information and digital content

Some specific goals for data literacy

The competence outlined by the framework ranges from fundamental to advanced proficiency levels. Fundamental proficiency is in part described as with guidance being able to "identify information needs", "find data and information in a digital environment", and "find how to access these data, information and content and navigate between them". Advanced levels of proficiency involve being able to "respond to information needs", "apply searches to obtain data, information and content in digital environments", and "show how to access to these data, information and content and navigate between them".

Other relevant data literacy goals include fundamentally: "identify how to organise, store and retrieve data, information and content in a simple way in digital environments.", and at an advanced level: "adapt the management of information, data and content for the most appropriate easy retrieval and storage"

Relevance to the GDSD

Though some of these goals primarily focus on being able to access information and data through search engines, they are broad enough to also include understanding and using data in general. Increased understanding of data, and how it can be collected and used, are therefore highly complementary competences to these goals. It is therefore important that the learning goals make students aware of what data is and how it can be used, as

well as how to read and analyse data. Other data literacy goals which involve storing and retrieving data are can also be relevant to Data Master, and these should be considered when designing mechanics for the game.

4.1.2 Curricular Learning Goals From schools

DL edu games may be made for different learning environments. One option is to develop a game for a particular class, but others may be more general, or focus on deployment outside a classroom setting. Instead of focusing on one particular class where the game could fit in, multiple sets of learning goals from various classes at Norwegian secondary schools were considered. It is important to consider curricula, when developing learning goals for educational games, to help maintain relevance. Excerpts from the official learning goals are included in appendix A.3, and A.2. Basing game learning goals on official curricula learning objectives also gives increases credibility, as the official objectives have been developed through a longstanding iterative process by a board of educational experts.[1]

Programming Elective

Many Norwegian secondary schools offer a programming elective, as explored in the research of Magnussen and Holst (2018). Though these electives do not explicitly focus on data, it is clear that learning more about what data is and how it can be utilized is still relevant. Here are some entries among the learning objectives of secondary schools:

- ”Velge og bruke relevante teknikker og verktøy for planlegging og utvikling av IT-løsninger”
- ”Definere variabler og velge hensiktsmessige datatyper”
- ”Programmere funksjoner eller metoder som blir aktivisert av hendelser”
- ”Utvikle og sette sammen delprogrammer”

Data and Electronics Elective

The data and electronics elective offered at some Norwegian high schools also contains learning goals of interest for the GDSD. Where the programming electives discussed above, focus on developing software, an area where data is often useful, the data and

[1] Official Norwegian learning plan resource: https://www.udir.no/laring-og-trivsel/lareplanverket/

electronics elective focuses on lower level code, and center more on hardware. The GDSD will involve design ideas of data collection from a physical sensor, as well as discussing virtual environments where students can deploy and utilize sensors that measure environmental data. Using the game to contribute to the data and electronics elective should thus be highly relevant. Here are some examples of relevant educational goals (læringsmål) from this elective:

- ”planlegge, montere, konfigurere, sette i drift, funksjonsteste, feilsøke på og dokumentere systemer for databehandling tilpasset mindre bedrifter”
- ”velge feilsøkingsstrategi og instrumentoppsett, anslå forventede måleverdier, måle elektriske størrelser og vurdere måleresultatet på data- og elektronikksystemer og -utstyr”
- ”bruke systemer for databasert måling og logging til feilsøking og vedlikehold”

From these excerpts, it is clear that a game that promotes and understanding of data, and how it can be used, would be highly relevant to the topics of this class. The GDSD should thus have learning goals that, when attained, contributes to the learning goals seen in schools.

Science (vg1)

Science is also a subject for which understanding data is highly relevant. A central theme in Data Master is sustainability, and players partake in gathering data from the environment, which is also relevant for science classes. Here are a few examples of learning goals that are relevant to this project:

- ”planlegge og gjennomføre ulike typer undersøkelser med identifisering av variabler, innhente og bearbeide data og skrive rapport med diskusjon av måleusikkerhet og vurdering av mulige feilkilder”
- ”skille mellom resultater og påstander og diskutere kvaliteten på metoder og framstilling av egne og andres data og tolkninger”
- ”bruke enkle datasimuleringer eller animasjoner for å illustrere og forklare naturfaglige fenomener og teste hypoteser”

4.1.3 Higher level data science education

When determining learning objectives for the topic of DL, it is important to consider what field experts say about learning data science.

In a medium.com article titled *Teaching Data Science - The Active Way!*, google developer Ta Chiraphadhanakul writes: ”Successful data scientists should also possess the ability to think with data — asking the right questions, framing problems properly, breaking down complex problems into manageable analyses, and more generally, having good data intuition.” Chiraphadhanakul outlines the importance of thinking with data, a skill that can be practiced by working with data and solving problems. Though his statement regards higher level education, it is important to consider, as increased data literacy may enable students to pursue advanced data topics when they reach higher education. Being introduced to data early, and getting rudimentary experience in solving problems with data is helpful in this regard.

4.2 Learning Goals

This is the first iteration list of learning goals. Being specific about the learning goals makes them trackable, such that to which degree the game is educational can be measured.

About what data is and how it is collected

- What data is
- What sensors are
- That sensors can collect data from the environment
- That data can be used to describe the environment

About how to use data

- That data can be analyzed to gain insights
- That insights from analyzed data can motivate actions
- That data can be used to monitor the effects of actions
- To use sensors to gather desired target data

- To use sensors to measure data from the environment

Higher level insights about data

- To compare data of different types and from different sources
- To solve problems using data
- To use sensors to gather specific data to solve problems

4.2.1 Rationale Behind Learning Goals

The learning goals are divided into three sections, which are sorted based on difficulty, from low to high. Having various levels of difficulty was chosen for several reasons. Firstly because students tend to learn at different speeds, and secondly because some students may have more advanced prior knowledge than others. One important function of the learning goals being able to measure learning. The learning goals also affect the design choices. Providing clear learning goals is also important for relevance to schools.

About what data is and how it is collected

This section of the learning goals focuses on the fundamentals. What data is and what sensors are, are important to understand as a foundation for further knowledge. However knowing what data and sensors are is also important in and of itself. These words are used often when working not only with data but with technology in general, so getting a proper introduction to what the terms are, with practical applications will thus be helpful.

More than what data and sensors are, the players should also learn the function of these things. Knowing that data is a measurement in the abstract is useful, but building on this by understanding that these measurements describe the environment makes the knowledge more applicable, and thus more useful. This contributes tho the fundamental knowledge needed to advance data literacy, specifically oriented around sensors, but this knowledge should also be applicable to other situations that require the use of data.

Why were sensors chosen

The reason why sensors were chosen as a means to teach data literacy is because to understand the fundamental questions of what data is, and how it can be used, can be very abstract. Such abstract concepts could often be hard to fully understand, and thus will

not get used. A goal of increasing data literacy is to enable people to use data to solve problems and advance knowledge. Sensors are perhaps the most direct way of collecting observable data; the concept of a sensor is easy to grasp and familiar to most people, who have used thermometers, motion sensors, or other similar instruments that measure the environment. Having a sensor measure something in the environment around the game players makes it easier to understand what the data the sensor collects actually represents, and thus it might enable players of the game to use data.

4.2.2 About how to use data

The next challenge is to use data. Knowing about how data functions is needed for understanding an increasingly data driven world, however knowing what something is is not the same as being able to use it. Data literacy involves not only understanding data but also being able to use it. And these concepts go hand in hand, as one obtains a better understanding of what something is by learning how to use it. Teaching the use of data not only furthers understanding of what data is, but it also empowers students to use data to solve problems. This could inspire students to learn more about data, or to pursue data as a profession, or as a subject for higher education. It could also help students to understand statistics that use data, to be aware of personal data challenges, and to innovate using data. It could also lead to a more data driven mindset.

The concepts featured in the learning goals also build on one another. The first point, about learning from analyzing teaches students a way to learn by using data. This is made useful in the next point which teaches students that the learning done in the previous point could motivate actions. Once action is taken, data becomes useful again, to measure how effective the action was. This reveals that data is not only useful to detect problems, but also to detect whether a solution is effective or not, or what parts of the solution were effective. The last point about learning to use data is to use sensors to solve problems, because sensors are the primary mechanism to collect data. So if one wants to use data to solve problems, sensors need also to be used.

Higher level insights about data

These learning goals were added as the high end of what some students might learn by getting a thorough and deep understanding of the previous learning goals. Some students may be able to reach these goals. Building on the previous concepts of learning how to use data, students now get measured on the goal of learning how to compare data, and solve

problems. Comparing data from various sources, and of various types, is significantly harder than comparing data from only one source. One has to account for differences in the environment and be able to draw conclusions by combining data, or be able to understand the relation between two kinds of data. An example of this is discovering that air pollution data levels near a road decreases in relation to increased measurements of wind speeds. One might the draw the conclusion that the wind affects the air pollution. Being able to work with this added complexity increases understanding because the fundamental concepts get tested again, and applied to a context that is closer to real world. Being able to use data in the real world is a significant benefit of data literacy, and this learning goal aims to facilitate that. Problem-solving with data using sensors is the highest learning goal, because a player who is able to do this is highly data literate. They should be able to understand risks and rewards of using data, how data works, and what one might do with data. Data is a useful tool, and the more students learn about data at an early age the better.

4.3 Measuring learning

This section is about the methods of measuring the learning. When creating learning goals, considering how learning could be measured is also important.

Measuring a student's test performance at key skills before and after playing the game, a method known as pre-and-post testing, is a reliable way of measuring learning. Using this method, the assumption is made that an improvement in test performance indicates learning. Using this method, however, incurs certain inaccuracies, and these must be addressed to maintain scientific rigor.

A central topic in this research is how the learning applies to real world situations. This is one of the main reasons for the focus on sensors in the research questions and game design. Being aware of the specificity of learning is important in these design processes. If players who do well at the game show little or no increased ability to solve the real world issues, the learning done through the game may not be relevant.

Chapter 5

Early Design Phase

5.1 Background

This project involved a game design process, which originally had the goal of making a DL game. However due to project changes, the design work was used to make the game design space document (GDSD). Because this is a design-science project, one of the central cycles of the project is design, which iterative cycles through building design artifacts, and evaluating them. This chapter discusses the early phase of design, where the end product was not yet clear, as well as evaluations done during these early iterations of design. The foundational ideas and concepts for Data Master were created first through an ideation process, and then further developed through a co-design session with a game design expert.

5.1.1 What is game design?

A satisfactory definition of game design is hard to arrive at, though Rouse (2014) argue that game design has to do with planning the different elements of a game, as well as player-game interaction. The design of a game in part dictates how the game feels to play. The term game development describes the creation of the actual game, which is different from game design which is about planning how the game should work, and why.

The research questions focus on designing games which are both engaging and and an effective at teaching DL.

5.1.2 A note on game literacy

One challenge with developing educational games is accounting for the variability in student's game proficiency. However with the increase in use of it devices, teachers report that students have far more advanced digital capabilities than was the case 10 years ago (see section 6.4.2). When using games as educational tools, players need to be familiar enough with games for them to be able to learn the intended material. Wong (2009) writes: "Today's youth have grown up accustomed to video games", in an article describing a large project to focus young students' digital competence into an effective educational tool to teach data literacy Wong (2009). This brings up the topic of game literacy, which is the ability someone has to understand a game, an essential skill for learning through games. Since 2009, when Wong described the proficiency of young students with digital tools such as video games, these technologies have proliferated to a far larger extent. Having a project with the basic premise that most young students understand video games is therefore reasonable.

It is clear that to play a game one needs some level of game literacy. This simply means that to play a game, one must understand how. By game literate players, this is done mainly by parsing the information the game presents to players, be it auditory, mechanical, or visual. As games have developed over time, designers lean on what has worked in the past. Doing so can be good design as experienced players will already be familiar with these elements, and thus will parse the game quicker. Over time, this effect accumulates, such that certain elements are taken for granted by designers and experienced players alike. However players who are new to games will not have been introduced to these mechanics, and thus may find them hard to understand. When making a game for education, players of various game literacy levels will be playing the game. Thus, making sure that the game is easy to understand even for players who are not experienced game players is important. Therefore, the game literacy required for the game should be as low as possible. This will be an important consideration when designing and selecting mechanics for the game.

5.2 Game Concepts

5.2.1 Ideation Process

Innovative design processes often start with an ideation process. In an article to explore the use of digital design ideation tools, Jonson (2005) ideation role in a design process: "[Ideation] is an essential part of the design process, both in education and practice".

During the ideation process this process, design ideas were generated, which makes up a backlog of ideas which could potentially be included in the final product. In this ideation process, using ideas from other games as reference material was crucial – ideas often build on one another. Iteration is an important tool, both in computer science and design. Basing design perspectives on existing frameworks of ideas, which exist in other game designs, can therefore be instructive in ideating good design. Therefore, a reference based approach was used during ideation.

The following is a selection of game ideas generated through this project's ideation process. They represent a backlog of design ideas which was ultimately used in the design examples in the GDSD. The ideaton process produced a number of ideas, and only some of them were selected for the expert evaluation. A full list of game design ideas generated can be found in appendix A.4.

5.2.2 Virtual Sensors

The function of the game is to teach data literacy, and focuses on learning about sensors and sensor data. A central game concept is thus to engage players in work with virtual sensors. By letting players collect data in a virtual environment, they can experience realistic problems related to sensor work, but these problems can be controlled and simplified to be appropriate for beginners. The use of virtual sensors became the fundamental concept for the game's design, because this was a direct way of addressing the project's primary goal of teaching sensor data literacy. Having the sensors in the game be realistic was therefore important, so that players might apply what they learned in the game to working with real world sensor. Having realistic virtual sensors as a core concept informed the design process moving forward.

5.2.3 Virtual Environment

The next game concept is the virtual environment, which goes hand in hand with the virtual sensors, as the sensors need an environment to measure. An example of such an environment is: a landscape with plains, woods, cities, and a lake. In the game players would deploy sensors into this environment to collect data about it. One engaging challenge that arises from this concept would be to have players make strategic decisions placing sensors. This could include what sensors to place, where to place them, or when to place them. The environment should provide some relevant factors that the sensors could measure, such as air quality, air pressure, temperature, humidity, wind speed etc. The sensors should allow

players to learn about the environment.

5.2.4 Tower Defense

One game concept considered was inspired by the genre of games known as Tower Defense. In these games players place defensive towers along a path, to defend against waves of invaders. Between each wave, players can build more towers, purchase upgrades, or in other ways change their defensive configuration to meet the escalating threats. Adapting this to sensor DL, players might be able to place sensors strategically in order to defend against escalating waves of enmity. However all sensors do is collect data, so for this concept to work while maintaining functionality that mirrors the real world, the villain of the game would have to be something which gets weakened by collecting data about it.

5.2.5 Fighting Pollution

Building on this, another concept is to have the villain be pollution. As discussed earlier in this report, the theme of the game should be sustainability. Having players combat pollution by using sensors is congruent with the goals for the game. An example of this would be detecting air pollution near a road, and seeing how it varies depending on weather and traffic. Players might also need to use different kinds of sensors to detect pollution in different areas, e.g. water pollution sensors in a lake, air pollution sensors in a city. However a challenge with using pollution as a villain is that detecting pollution does not directly defeat it. In tower defense games, players defeat invaders, it is insufficient to only detect them, which is what sensors do. This leaves an unresolved question of how players would combat the detected pollution. One option to solve this is to have the game clear discovered pollution automatically. Another option is to add a game mechanic for fighting pollution. When design challenges can be solved by adding more mechanics, it is important to consider the scope of the game. Adding more mechanics might cause either complexity creep or scope creep.

One idea considered to allow players to combat pollution is to allow them to place anti-pollution technology, eg. water filtration technology. Such a mechanic is in line with the genre of tower defense discussed above. Players might for instance make choices about resource allocation, to detect pollution and stop it. They would have to balance their budget between sensors and cleaners, and make sure to use these efficiently. One issue with this solution is that it takes away focus from learning about sensors and sensor data, and puts more emphasis on resource management. Since the game aims to teach data literacy, the

challenges in the game should preferably mirror those of working with sensors in the real world.

5.2.6 Data Comparison

Another game activity that was considered was to have players compare data. When working with data, analysis is decidedly central. Going from so called 'raw' data, to knowledge often involves aggregation, such as averages, but in many cases also involves comparisons of data, or looking at various data in a larger context. Looking at separate measurements together can guide data analysts to glean insights. An example of this is measurements of air quality and temperature, which alone only provide a picture of how these factors change at different times, but when looked at together, one can observe that temperature seems to affect air pollution. Since this is an important utility of data driven work, it could be a very potent inclusion in the game; it might help facilitate students into learning about how data related work is done in the real world. A challenge with game mechanics related to this is that they can become very complex, or difficult, so making sure this is accessible and well explained is necessary, to avoid confusion, and make students focus on the desired aspects of the game.

5.3 Game structure

The game concepts discussed so fare have not been directly related to structure. How the game flow is, what actions players take from beginning to end and how these mechanisms are framed and presented are also important to address. A few game structures were generated.

1 One structure is to have players aim to reach as high a score as possible, by using sensors to detect pollution and using cleaning mechanisms to combat them. This kind of structure is known as survival, as the player is not trying to win, but to avoid loosing for as long as they can. **2** Another structure is for players to be given a polluted environment, and have them chart and detect the pollution by using sensors, under a time limit. When the pollution is tracked well enough (when enough data is collected), players move on to the next level. This is a level based structure, which is a good way to present players with controlled challenges, that accelerate in difficulty. This structure is also ideal for introducing mechanics gradually — early levels use a smaller subset of the mechanic pool, and more mechanics are added at a comfortable learning pace. **3** The third structure for

Figure 5.1: Sketch of Design Ideas

the game is to have gameplay be centered around alarms. Players have to set up a system which defends inhabitants of the virtual environment from pollution by raising alarms at critical amounts of pollution. This involves the use of control engineering, finding the correct values to use for the alarms, and collecting data efficiently. This flow of gameplay could involve both a level based and a survival structure, where players have to survive until a timer runs out, and if successful, they advance to the next level. Combining these structures can be useful because the benefits of both approaches can be utilized, but it also makes the game more complex, which may halt development. An advantage of this model however, is that if the scope must be reduced, having only one level is an option, with the possibility of adding more. This structure creates a lever for scaling the game.

5.4 Design-Sketches

Spikol and Milrad (2008) discuss the use of sketching, as a conceptual design tool for ideation. Sketching was one of the conceptual tools used, and the following is an exploration of one instructive design sketch for game design concepts. Figure 5.1 is a sketch of four game design concepts which were explored in the iterative ideation phase.

Figure 5.1 shows four design ideas, sensors and data related items are drawn in red. The following is an explanation of the design concepts illustrated in this sketch:

(1) In the top right panel we see one example of using sensors, where an environment with mountains, water and trees is shown from the side. Sensors are placed at various locations, which collect data from the environment. We also see the data listed on the left, as an interface element.

(2) In the top right panel we see an illustration of how a real world sensor could interact with the game. A sensor is plugged into a tablet, where we see an overview of virtual sensors in a virtual environment, with some overlay for collected data. Using real world tools is a powerful design option to facilitate the real world applicability of what the game teaches.

(3) In the bottom left panel we see a 3d environment with forest, road, lake and city, and an overlay with sensors and data. One concept which was also used later in the project, when developing a boilerplate implementation, was to have sensors be placed in a 3d environment, where the gameplay centered around finding good positions to place sensors and collect data.

(4) In the bottom right panel we see a still image of a natural environment, involving ocean, trees, mountains, and a parking lot to the right. Each of these locations have a pollution meter which is filling up (although pollution is only one example), and sensors are aiding in detecting the percentage of pollution. This is a more simplified interface which could draw focus more towards data analysis and visualization, instead of focusing on placing and managing sensors.

This sketch and the explanations were included in the GDSD, to show ideas from the game design space.

5.5 Expert Evaluation of early process

After a substantial ideation process, several concepts of various levels for what the game should be, were developed. In the method of design science outlined by Hevner, a scientific approach to the design of an innovative artifact is essential. One of the goals of such a process is to enhance rigor – an effort to make the artifact satisfy its purpose. One of the ways to maintain scientific rigor throughout the design process is to employ expert evaluation. An expert in a field can discover problems and make critical observations which, after being addressed, increases the quality of the artifact. Thus a game expert was consulted early in the design process, to give feedback and evaluate both the design ideas and the design process.

The first expert consulted was *Expert0*, who is an associate professor at NTNU, under the institute of design. Expert0 has contributed to several publications about design, and lectures on several subjects at the university, one among which is game design. In his game design class, he teaches principles of game design, evaluates games made by the students, and gives counseling throughout the design process. Expert0 was asked to evaluate various aspects of the design and development work at the early stages of the process, and was then engaged in a co-design process to further develop the ideas.

5.5.1 Methods

First the literature base, and the methods to be used in the project were discussed. The method presented to the expert was the design science method described by Hevner (2007) , with the three cycle design view, discussed earlier in this report (see 1.4). Expert0 found the method appropriate, however he suggested several additional sources to further investigate design methods, among them Frayling's model of design. Adding complementary perspectives on how methods of science can be useful, so further investigations were made, however because it was found to be solid by the expert, it was kept as the fundamental method for the project.

5.5.2 Game Engine

The primary tool for game development is the game engine. The definition of game engine as: "a framework comprised of a collection of different tools, utilities, and interfaces that hide the low-level details of the various tasks that make up a video game" Anderson et al. (2008)

Before the meeting with the expert, three game engines were selected as candidates for developing the game: *Game Maker Studio 2, Unity,* and *Unreal Engine*. These were selected because of the authors previous experience with the engines. The selected engines are also highly accessible due to being free to use, with widespread adoption in teams of various sizes.

Upon consultation with the expert the **Unity Engine** was selected for this project, for any game development work that might be done. The reasons for this choice was the engine is: free, easy to use, and has a wide base of developer content. A discussed idea at the time was using a real world sensor to interact with the game as an add-on, the implementation of which was feasible in Unity. However this idea was later scrapped for

the project, due to reducing accessibility, which was highly argued for by teachers (see section 6.1).

The Expert recommended Unity arguing its position as ”industry standard, which is always a solid option”. He also added, anecdotally, that the Unity engine is widely recommended by other game design experts in academia. Alternative engines like Unreal and Game Maker Studio were considered, but they were deemed less viable, the former due to being heavier than needed, the latter due to lacking appropriate development flexibility.

5.5.3 Pitfalls

Expert0 outlined two primary pitfalls for the design of educational games. The first pitfall is separating learning and gameplay. An unsuccessful approach is the use of gameplay as a carrot, a reward for doing the learning part of the game. The expert argued that a good approach to avoid this pitfall is to design with the goal of making the learning engaging, through gameplay.

The other pitfall Expert0 described was making the learning in the game too indirect, or implicit. The expert argued that the game must be clear in what it is trying to teach. Otherwise students will struggle to apply anything they learned in the game to real life. An advantage for classroom use is that the teacher can take the job of teaching students how to apply what they learned in a game to real life. Games designed for out-of-classroom contexts should therefore be thorough about designing for students to understand how the material they learned applies to the real world.

5.5.4 Games vs Simulations and choices

Choices play an important part in distinguishing a game from a simulation, according to expert0. It can be hard to produce a satisfactory definition of a game. However it is clear that a game, being an interactive medium, needs to present its players with choices. Simulations are also interactive digital media, but in a digital simulation environment that is not a game, the player does not risk losing based on making the wrong choices. Engagement in games often comes from the challenge of making correct choices with the constraints that the game provides, according to the expert. When exploring game concepts, some attention will be placed on what kind of choices these game concepts could present to the player. One of the goals of the game’s design was to be engaging to players, and ensuring the possibility for engaging choices in the game’s design must therefore be pursued.

5.6 Co-Design Session with Expert

”Co-design can be defined as highly facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation...” Spikol and Milrad (2008)

One of the concepts explored by the co-design session with Expert0 was for the game to involve realistic sensors. An advantage of having students play a game in which they would simulate using real-world-like sensors, is real world similarity. If players learning about how sensors work in the could apply that knowledge to real world work with sensors, central DL insight would be gained by the student. This became one of the promising conceptual pillars on which game design ideas for Data Master was built, however it is doubtless that there are many other viable options for teaching sensor data literacy.

Several game concepts were suggested during the session, involving various virtual environments where sensors could be placed to make measurements. In some conceptualizations, players could interact with various aspects of the environment like a simulation, and see how the various factors affected the resulting environment. For instance they might place sensors near a road and see the effects of changing the speed limit using sensors like air quality and noise. Another option was to combat invading pollution in an environment by using sensors and actuating preventative measures, such as filtration technology for water pollution. The final concept, which was the concept deemed as having the greatest game design merit for the task at hand was to let players place sensors in a virtual environment populated by people. These people would be affected by the pollution in the area, but could evacuated when an alarm sounded. Players would have to place sensors to figure out the levels of pollution, and at what levels of pollution an alarm should sound. This also involves a level of control engineering, which might make the game more relevant for natural science classes at schools. Notes and sketches from the co-design session are included in appendix A.5 as documentation.

5.6.1 Designing Feedback from the Game

Feedback is essential for both game design and learning. A player of a game needs to understand the cause their actions, and this is communicated from the game through feedback. Similarly, teachers must give feedback to students to let them know whether what they are doing is good or not. In 2007 John Hattie and Helen Timperley wrote an article called ”The Power of Feedback”, in which they state ”Feedback is one of the most powerful influences on learning and achievement, but this impact can be either positive or

negative." The article details what is known about feedback as it relates to learning and achievement. In it they distinguish between various forms of feedback, and propose a model detailing the most important contributing factors that determine whether feedback has a positive or negative impact on learning. They also suggest some best practices for effective feedback in the classroomHattie and Timperley (2007). They explain that direct praise is not as valuable for teaching, as specific feedback grounded in expectations and observations. With this article as a basis, the design of the feedback in the game was evaluated, to avoid pitfalls of feedback in education, and improve the quality of feedback in the game.

Chapter 6

Evaluation

This chapter describes the evaluations that were conducted after the first expert review. At this stage of the project, ideas and concepts for data literacy games had been described, based on feedback and co-design session with the game expert. The following evaluation focused primarily on learning goals. This chapter describes educational expert feedback on the learning goals (developed in chapter 4). This feedback was important, as relevance is one of the three pillars of design science. With no such evaluation, a risk arises that the tools designed are not useful to its target group, and thus does not serve a purpose. Conducting evaluations with teachers was therefore a priority.

Consulting users is key during the design of educational games. An example of using SSIs to get user feedback to inform the design process of a data literacy game was discussed in the literature review at 3.3.8. Guo and Goh (2016) argue that ”educational games frequently fail as users are not included in the design process”. Therefore, using SSIs to gain user feedback from students was also a priority.

The evaluations described in this chapter targeted teachers and students, as representatives from the two fundamental groups that make up the educational system. This chapter describes several semi-structured interviews (SSI) that were conducted at a Norwegian lower secondary school. In total, 5 teacher respondents were interviewed, 3 one-on-one interviews and 1 pair interview, as well as 1 interview with a group of 6 ninth-year students. The first of these was a pilot interview with a teacher. The teachers served primarily as educational experts, but also provided some user feedback. The students were interviewed as users.

An interview plan was created in advance; its design process is described in 6.2.2. Due to the nature of SSIs, the interview structure varied based on conversation with respondents. Despite this, the topics planned for the interviews were fully covered, however some additional topics were discussed in individual interviews. For instance some teachers would bring up topics of game mechanics or make suggestions to how the game could work. The interviews were conducted in Norwegian language, however quotations have been translated to English by the author of this report.

6.1 What was evaluated

The main focus of the evaluation was the learning goals, which were evaluated for relevance. However feedback the project, as well as some feedback on game concepts was also collected. It was important to identify challenges with teaching data literacy, and attitudes towards educational games, as reflected by the research questions of the project, further discussed here 6.2.1. Before the interview, several ideas and concepts for the game had been developed, and the plan for the project was to get feedback from teachers and students to determine which direction to move the design forward in. However due to changes in the project plan described here 1.7, the game design feedback was instead used to explore different possibilities in the final game design space document.

6.1.1 Initial Learning Goals

The following is a list of the the learning goals that were evaluated, as they were formulated going in to the interviews:

Learning Goals Iteration 2

By playing a Data Master educational game, students should learn about:

About what data is and how it is collected

- What data is
- What sensors are
- That sensors can collect data from the environment
- That data can be used to describe the environment
- Using multiple sensors
- Using sensors over time

About how to use data

Analysis

- That we can learn by analyzing data
- That what we learn from data can motivate actions
- That data can be used to monitor the effectiveness of actions

Visualization

- That data can be visualized
- That data show different things depending on visualization method
- Determine appropriate visualization methods

Sensors

- To use sensors to gather desired target data
- To use sensors to measure data from the environment

High level insights

- To compare data of different types and from different sources
- To solve problems using data
- To use sensors to gather specific data to solve problems

6.1.2 Game Concepts

Game concepts were also evaluated. In the interview with teachers, some feedback was given about game concepts, but focus was on learning goals. During the student interview,

focus was on game concept discussion and feedback.

The game concepts evaluated in were outlined in section 5.2

A flyer was also given to the participants to help visualize the game and understand the project. The flyer is further described in section 6.2.2.

6.2 Interview Method

This section describes the interview method, focusing on scope and design of applied research tools. The section also describes the purpose for the interviews. The interview method and data analysis in this interview has primarily been based on the books *Analysing Qualitative Data* by Gibbs (2018), and *A Companion to Qualitative Research* by Flick et al. (2004).

6.2.1 Purpose — Research Questions

The primary purpose of this set of interviews was to develop the project's relevance. The interview focused specifically on the set of learning goals for the game, expecting feedback on both its quality, and its relevance to school curricula. Feedback on game concepts and attitude towards educational games was also explored. In these interviews, the teachers were seen primarily as educational experts, giving their professional opinions, however some questions were answered from more of a user perspective, i.e. the teachers envisioned how they might use the game in a classroom setting.

The interviews were done to make progress towards answering the research questions. This section summarizes how the interviews related to the research questions.

***RQ1**: How should games be designed for teaching data literacy to Norwegian secondary school students?*

Getting teacher feedback on both the topic, and the method was crucial to advancing this question. Teachers are experts at teaching secondary school students, and understanding their perspective was therefore important to understand how to design DL edu games.

***RQ1.1**: How can data literacy games be designed to be engaging for Norwegian secondary school students?*

The teachers interviewed, having wide experience in engaging students, provided feedback on how to engage students, explored bellow. This research question was more heavily

emphasized in the student interview.

***RQ1.2**: What challenges do Norwegian secondary school students face when learning data literacy?*

During the interview, it was shown that teachers had experience using games and teaching data literacy. As educational experts, they contributed feedback exploring the challenges students face when learning about this topic, and also had ideas on how to meet these challenges.

***RQ1.3**: What are key concerns when designing DL educational games for the classroom context?*

which was also addressed in these interviews. When developing innovative teaching tools, it is important to consult with teachers who have competence and experience in education. This is to make sure that the tool is relevant to the teachers' needs, which not only guarantee that the game has relevant and useful learning objectives, but also that the game is accessible and usable for teachers.

***RQ1.4**: What should be the learning goals for a game teaching sensor data literacy?*

Consulting teachers on learning goals was the main focus during the interview. Teacher feedback on learning goals was essential, as they have hands on expert experience of teaching secondary school students. The learning goals were therefore the focus during the teacher interviews.

An outline of research questions can be found in section 1.2

6.2.2 Participants

The participants of this interview were teachers of varying ages and levels of experience. They primarily taught math and science, and one of them also taught a programming elective. One teacher had experience teaching algorithmic thinking, and they all used statistical visualization as part of math curricula. Some data collection was also part of science curricula, getting pH readings from water, or using data loggers, both methods having students collect their own data. The teachers thus had some experience teaching data literacy, and found learning the objectives relevant in this regard. However focus on data literacy in the classroom was limited in their experience.

6.2.3 Flyer

A flyer was designed for a data literacy game, to give something concrete for respondents to look at. This is important because the subject matter is highly theoretical, and teachers may find it challenging to understand what a data literacy game could look like, or struggle to remember the contents of the project. The flyer was intended to help teachers envision a product, enabling them to respond to questions about the concepts, and give qualitative feedback.

The main purpose of the flyer was to give insight into the project, but it was also gave respondents an opportunity to discuss game concepts. Teachers have different experience playing games, so the interview plan did not include questions specifically related to evaluating game design. However during each interview, game concepts were described. The main reason for this was to help teachers understand the context for the learning objectives and to understand the vision for the project, which was intended to help them give good feedback. Some teachers also gave feedback on the design concept, or came up with design suggestions. Though this was not the primary focus of the interview, design feedback from teachers is valuable to the project, and was thus included. An advantage of the SSI structure is that it allows for valuable feedback to be received even if it was not planned for in advance.

At the start of each interview, teacher respondents were given the flyer, and they were encouraged to use it for clarity about the project's aims and goals throughout the interview. The flyer contained a title, a pitch, some ideas and some pictures. The pictures were of young students working with sensors and computers, and an image of a virtual environment taken from a unity asset package.

This is the flyer given to the teachers:

DataMaster

Spillet som lærer elevene hva data er, og hvordan den kan brukes

Utforsk med sensorer

Bruk fysiske og virtuelle sensorer til å utforske hva man kan gjøre med data. Gjør målinger og vurder dataen, for å bekjempe luftforurensning!

Ved å spille dette spillet blir elevene utfordret til å finne ut hvordan de kan bruke sensorer til å forstå miljøet rundt dem. Spillet er rettet mot bærekraftsmål, og handler om å detektere og bekjempe forurensning. Å forstå data blir viktigere og viktigere i samfunnet. Ved å håndtere realistiske datarelaterte problemstillinger blir elevene rustet til å kunne bruke data.

Lars Møster
Master Informatikk NTNU
94237502
lars.moster@hotmail.com

6.2.4 Semi-Structured Interviews

The interviews conducted during this evaluation were all semi-structured interviews (SSI). In this set of SSIs, topics were planned, and some questions around the topic, but otherwise the structure was kept loose. It was important to generate rich qualitative feedback, and allow the teachers to bring their own experiences and concerns, unimpeded by the interview process.

Gibbs (2018) describes the qualitative method used here as seeking to get rich feedback, to describe what is happening. ”The description is detailed and contributes to and understanding and eventual analysis of the setting studied”. Because this set of interviews had several experienced respondents, each interview lasting about 40 minutes, a large amount of qualitative feedback could be collected. The sample size and the amount of time allowed for deeper and richer qualitative data, so the choice of method was intended to compliment this.

The SSI format was chosen because the goal of this set of interviews was to get rich, qualitative feedback from respondents. ”This type of interview gives the researcher opportunities to probe for views and opinions of the interviewee” Kajornboon (2005). By using too rigid of a structure, one might omit important details, or miss feedback that was not anticipated. A more open structure allows teachers to use their experience and knowledge to provide the kind of feedback they deem important. It also gives the interviewer the flexibility to ask followup questions or spontaneously dive into different topics that come up during the interview, which might be relevant to the project. Because of their qualitative nature, SSIs are useful even with smaller sample sizes.

6.2.5 Teacher Interview Plan

This is the interview plan developed for the teacher interview:

Semi-Structured Interview Plan, for early evaluation of learning goals and project relevance, with teachers:
This is the interview plan for teacher interviews

Purpose

The purpose of this interview is to develop relevance for learning goals for the data literacy game. These are questions for attaining this purpose:

- Are the learning goals relevant for school curricula?
- How familiar are students with the material?
- Are the learning goals too basic or too advanced?

Sometimes in SSIs, questions are not fully planned, topics are planned and questions arise as a matter of course. This document therefore includes some topics for the SSIs, and questions that should be answered throughout the interview either directly or indirectly. These questions are only there to facilitate discussion, and will only be explicitly asked if needed.

Introduction

Explain the project and what data literacy means. Explain the purpose of the project and of the interviews. The game should be realistic and enable students to learn more about sensors, and perhaps pursue a career in this. The game could be useful as a preliminary for Micro:bit, or other sensors in Naturfag og programming.

Part 1 - General

General topics to form a basis for the teacher's perspective a data literacy game in the classroom.
Challenges:

- Do you have any experience with teaching the topic
- What are challenges when teaching a topic like data literacy?

Student Data Literacy level:

- What is the level of data literacy of students?

Games in the classroom:

- How much experience do teachers have with using educational games?
- What is useful when using games in the classroom?
- What are the constraints of using games in the classroom?

Part 2 - Learning Goals

Developing learning goals that are: 1 relevant, 2 appropriately challenging

- On the topic of sensor data, what is an important learning goal to be pursued in an educational game?

(present list of learning goals and talk about them)
Questions about the list of learning goals:

- How relevant are these goals for school curricula?
- How could these goals be made more relevant?
- Which one would you remove if you were to remove one?
- What would you add if you were to add learning goals?
- Are any of the goals too advanced or too basic?
- How many can reasonably be hit?

6.2.6 Student Interview Plan

An outline was also made for the student interview, although this plan was more open ended, as the goal of the student interview was to discuss game concepts and get user feedback and suggestions.

U0 Student User Interview

This is a semi-structured interview (SSI) plan for a student interview about DL edu. game concepts

Purpose

(1) To get student perspectives on games, especially related to learning. **(2)** To get user feedback on design concepts and gauge interest in the project. **(3)** To get design ideas, directions, and suggestions for what students want to see in DL educational games.

Description

A brief description of the project and the game concepts was given. A virtual environment where players learn to use sensors, perhaps by competing or cooperating. The flyer is used to help students understand the project, and the game concept.

Introduction

It's a single player game, but could or maybe should be played collaboratively. Use real examples from real life. The games design should emphasize that these scenarios are realistic, and useful for real life.

(1) Background questions

- Do you play games?
- Have you ever played games in class?
- What is fun about playing games in class?
- Can you learn from playing games?
- Have you learned about data, if so how much?
- Have you heard about data literacy? (in simpler terms)
- How interested are you in the topic?

(2) & (3) Questions about the game and concepts

- Is the game as described or its subject matter?
- Would you enjoy a class using such a game?
- Could you learn something by playing a DL educational game?
- Do you like the idea of a virtual environment?
- What would make the game more interesting to you?
- What game elements do you usually find engaging?
- What would you add to a game about data?

(Note that not all these questions will be asked during the interview, they are just examples of how to explore the theme, but the flow of conversation will also dictate which direction the interview goes. This is a property of SSIs)

Interviewer guideline

User 0 - Students, Bergen. Talk about game concepts developed with Exp 0, and if ready show progress for development. They should talk about what they may and may not like from the concepts, and what they think they would enjoy in an educational game - specifically one about sensor data. Be as specific as possible, we have a lot of general ideas from literature about game elements students find engaging. Bring this list to them and try to determine how it could be integrated into a game about sensor data.

This is a list of design ideas to be discussed if needed during the interview:

- Virtual Sensors
- Virtual Environment
- Actual Sensor
- Pollution as enemy
- Data Collection
- Data Comparison
- Clean up environment? In a given time?
- Arcade style with High Score?
- Survive until next level?
- How fast can you beat it?
- Use data to convince people to take action, eg. convince politicians.

6.2.7 Feedback Collection

Using a qualitative method, some subjectivity will arise, which is also required for doing creative work such as design science. It was, however, important during the interviews, to maintain focus on scientific rigor. For this reason, leading questions were avoided, and open questions were prioritized when possible. Corrective listening can also occur during SSIs, so focus was on taking accurate notes that were reflective of what the respondent said. There are, however, challenges with conducting an interview and simultaneously taking notes, so completely eliminating subjectivity was impossible. Some listening and note taking techniques were used to maintain high accuracy throughout the interviews; here is an incomprehensive these techniques, used for accuracy and rigor:

- Asking open questions
- Repeating back statements to confirm understanding
- Asking clarifying questions
- Pausing to write down accurate notes

- Taking observational notes

6.2.8 Data Analysis Method

This section describes how the qualitative data was analysed during and after the interviews.

Data Analysis Plan

A plan was created to facilitate the process of data analysis, and plan the structure and sequence of the operations. This is the data analysis plan:

This is a data analysis document for the SSI's done with teachers to develop project relevance.

Planned Topics

Some topics were planned in advance. Here is a list of topics:

1. Game design feedback
2. Educational game feedback
3. Project oriented feedback
4. Project relevance feedback
5. Learning goal relevance feedback
6. Learning goal formulation feedback
7. Data literacy feedback
8. Respondent background information

Recording feedback During the interview notes were taken to represent respondent answers. A bias can exist here, but focus was on objectively noticing and transcribing the interaction. The researcher has 3 years experience as a group facilitator, training to objectively observe and record group interactions, which aided in this research process.

Process of analysis

After the interviews analysis of the results was conducted. Here are the ways results were analysed:

1. Read notes and transcripts
    (a) Comparing results from different respondents
    (b) Drawing parallels
    (c) Investigating contrasts
2. Sort feedback into categories
    (a) Start by using topics for interviews
    (b) Look for emerging themes
    (c) Look for overlapping categories
3. Summarizing feedback
    (a) Drawing out essentials
4. A Discuss implications for project
    (a) Selecting supporting phrases and quotations
    (b) Comparing with expectations
    (c) Adapting project based on feedback
    (d) Comparing with literature
5. Visualizing feedback
    (a) Create graphs to visualize data
    (b) Illustrate project changes as a result of feedback

With the planned structure in mind, the following is a description of the data analysis method used during and after the interviews.

Data Part 1: Field Analysis

When doing semi-structured interviews, one advantage is that the process of analysis can start on site. this is true of qualitative data in general, but SSIs provide the interviewer

with the flexibility to pursue topics of interest further, clarify stances and information, and discuss topics back and forth. This process can be seen as the first step of analysis, and it happens simultaneously with the data collection. It is important – when conducting such interviews – to be mindful of biases or selective listening which might affect the data. Gibbs describes this further; ”Analysis can, and should start in the field” in *Qualitative Data Analysis* (p16), explaining that qualitative researchers have the ability to start analysing data from interviews on site, by taking and examining notes. Making observational notes, writing down, according to Gibbs (2018), ”as concrete and detailed as possible what you saw, heard, felt, tasted etc.” can add to the process of field analysis, as it gives context for the words spoken. This context is useful for understanding responses.

Part 2: Post Interview Analysis

Comprehensive notes were taken during the interviews, and these notes, were analysed in post. As outlined in the data analysis plan, the focus of the post interview analysis was to look for themes. Coding was chosen as the method for analysing the notes, a method for identifying a theoretical or descriptive idea from the data, according to Gibbs (2018). After reading the documents thoroughly, themes of feedback emerged, either through repetition, through reflection, or through respondents themselves highlighting a comment as important during the interviews. The notes were coded based on these emerging themes. According to Gibbs (2018): ”Coding is how you define what the data you are analyzing are about”.

6.2.9 Ethics and Formalities

In these interviews leave was given to conduct interviews by teachers who had agreed to be interviewed. Teachers received an email invitation to attend the interview via the head master, in advance, so volunteers arrived to the interview room according to their individual timetables. To get as many participants as possible, one interview was done in pairs, as two teachers could only attend during one time slot. An advantage of having semi-structured interviews is that it allows for the flexibility to adapt to situations like this.

Because personal data was collected from neither the teachers nor the students, no application was sent to the NSD (Norwegian Centre for Research Data) regarding the interviews. The goal of the interviews was to get feedback on the project from relevant target groups, so no personal data was needed. Notes were taken by hand; no voice recording was used. Not being able to record did put heightened demand on note taking for data col-

lection. Due time was taken to ensuring accuracy of notes, even without exact transcripts of the interviews.

6.3 Pilot Interview

First a pilot interview was conducted. The first respondent was a teacher of math and science. He had some experience teaching data through the statistics-+topics in math, as well as some data collection in natural science. After being introduced to the project, he was interested, displaying clear optimism about its merits.

6.3.1 Purpose

Having a separate pilot evaluation allows some preliminary iteration, both on the interview process itself, and also on the learning goals. This is useful because errors can be fixed early so as not to affect the following interviews. Often only a small amount of feedback can reveal seemingly obvious errors, inaccuracies, or confusions with either the interview plan or the design for which feedback is sought. The purpose of this set of interviews was expert feedback on the learning goals, and the pilot interview enabled further iteration on the goals. Thus the remaining interviews could go on after having made iterations based on the pilot interview.

6.3.2 General Feedback

The teacher was interested in the project, stating that ”understanding data becomes more and more important”, and that ”data should be a bigger part of the curriculum”. He also lamented the lack of equipment to do more data related activities in the classroom. This feedback indicates that the project is relevant for education, and that assertions about the importance of data education are reflected in teacher attitudes.

The teacher was convinced that games can be useful for education, by engaging students in novel and interesting ways, or by giving them an arena to compete in. During the interview, the teacher emphasized the importance of the game being easy to understand and to use. It was also important, according to the teacher, for the game to be adequately challenging but not overly difficult. ”Do not underestimate the students” he stated, indicating that students are generally good at understanding games, thus making the game too simple risks boring them.

6.3.3 Learning Goal Feedback

The teacher underlined that its important for the learning goals to include an understanding of why sensors are used. Building on this, a focus on the importance of the actions and methods was added to the learning goals. He, however, emphasized that the goals were highly relevant for various curricula in subjects he teaches. ”Especially the points about visualization” he said, indicating that he considered visualization to be an important area for the game’s learning objectives, because of its relevance to math curricula. The teacher advised that the project should focus more on this.

6.3.4 Pilot Interview Changes

After the pilot interview, the learning objectives were altered and reformulated, based on the feedback received. The teacher wanted the objectives to be more specific, so some specificity were added, eg. ”Using multiple sensors” was changed to ”Why and how to use multiple sensors”. Examples were also added to some of the learning goals, to make them easier to understand, for instance the goal ”Taking actions based on data” was appended with ”eg. reduce traffic in a polluted area”. More emphasis was also placed on understanding the importance of activities. For this reason, ”That data can be used to describe the environment” was changed to ”Why it can be important to use data to describe the environment”. After these changes, the learning goals were ready to be evaluated during the next set of teacher interviews. Though changes could also have been made to the interview formula, none were made, as the teacher interviewed for the pilot evaluation showed great enthusiasm, and was able to understand the project and provide useful feedback.

6.4 Teacher Interviews

After the pilot interview, 3 additional teacher interviews were made, 2 one-on-one interviews and 1 pair interview.

There was an abundant amount of feedback from the teacher interviews. One primary observation was that the teachers were enthusiastic, and interested in the project. This is important because as educational experts, teachers have insight into what kind of tools could have teaching potential. Optimism from teachers about the project indicates that it has potential for education - which in turn implies relevance.

6.4.1 Participants

Table 6.1 shows an overview of teacher respondents, including what subjects they mainly taught, and what type of interview. An ID was given to each respondent, to better reference their feedback specifically.

Teachers Interviewed			
Main Subject	**Interview Type**	**Years of practice**	**ID**
Math & Science	Pilot	14	T01
Math	One-on-One	11	T02
Programming	One-on-One	7	T03
Science	Pair	1	T04
Math & Science	Pair	18	T05

Table 6.1: Teacher Respondents

All 5 of the teachers interviewed stated that if a DL game was developed as described by this project, they would use it in their classes. When asked whether they would use a data literacy game as described, respondent T04 said: ”I would use a game like that for sure”, and similar sentiments were uttered unanimously among respondents. However, the teachers also emphasized that to use such a tool it needs to be easily **accessible**. Teachers mentioned and discussed several potential accessibility concerns. Here is a list of concerns teachers mentioned about the accessibility of a data literacy game:

- The game being free to play in educational settings
- That the game runs smoothly on devices that both teachers and students have access to, such as Chromebooks
- Students being able to understand how to use the game
- Students getting the instructions in their own language
- The game being understandable for students who lack experience playing video games
- For the game to be quickly learnable for students
- That teachers could conveniently include the game in their educational activities

6.4.2 Convenience and Ease of Use

There exists overwhelming amounts of digital educational tools which could potentially be useful. However teachers only use a small fraction of them. Respondent T05 claimed

that convenience was the most important issue for teachers. ”If it is inconvenient, a teacher may be interested and it could look useful, but it will never be tried out because the teacher does not have time to learn how to use it.” Among respondents there was a shared sentiment that teachers have busy schedules, which leaves little time to explore the use of new educational tools. ”Teachers are busy!” says T05. To accommodate this concern, data literacy educational games should be designed to be easy for teachers to learn how to use so they can be implemented in the classroom with minimal effort. ”Ideally it would load up and the student can just play and learn on their own”, a statement made by T02, describing how to do ease of use in educational games.
Several teachers mentioned potential accessibility concerns for students' ease of use. Respondent T05 preceded with the following: ”If learning a game takes too long, teachers will be unable to use the game in the classroom, because the time investment would be too big compared to other educational activities.” According to the teachers, for the game to be used in the classroom students need to be able to learn it quickly. Game development of data literacy educational games should therefore be designed with emphasis on learnability, especially if intended to be used in classroom settings.
T04 and T05 also pointed out, in their pair interview, that students are more digitally literate than before. They argued that this makes games more effective teaching tools. Because of the usage of cellphones, tablets and other digital devices from a young age, the proficiency with using digital tools such as games has increased substantially over the last decade, according to T05.

6.4.3 Readiness to use games in school

The teachers also had some experience using games for education, and noted that games can be useful educational tools. The primary reason for not using games more often in education was accessibility, or ”lack of competence”, as two teachers independently put it. Teachers do not have access to games that teach relevant material, and that are also easy enough to use to be worth the time invested learning to use them from both teachers and students. The level of game literacy among students is also highly varied, as some play more games than others. New educational games therefore need to account of these issues when developed.

6.4.4 Game Design

Game design ideas were also discussed during the interview. When discussing general traits which make educational games useful for education, teachers suggested engagement

– through emersion and novelty – and adaptability. Engagement is important to facilitate learning, and adaptability enables games to be played by players of widely different experience levels, and interests. Game design should thus emphasize these traits, especially if made for the classroom.
When discussing game structure, some teachers preferred games which could be played to completion in one sitting, of 1-3 hours, while others preferred games intended for multiple uses throughout the semester. They also agreed games designed for multiple sessions should be played individually, but games made for focused one-time use could involve elements of cooperation. These opinions indicate that there is big potential for differently structured educational games that could facilitate learning for students in and out of the classroom. The interest teachers showed for different kinds of games was a key reason for using the GDSD format, as making a single game design was insufficient to meet the demand.
Some game concepts were also discussed with teachers, as hypothetical ways of making a DL educational game. The discussion centered around a game containing a virtual environment where players could deploy sensors to detect pollution. Teachers were interested in the topic of visualization of data, and how this could be explored in a game. An example of a game mechanic developed in discussion with T03 is letting players represent their data using visualizations such as graphs etc. One option to facilitate mathematical learning would be to let players choose between multiple ways of representing the data statistically. The game would reward players for choosing appropriate visualizations, thus learning both data literacy, and statistics, in an applied way. This is an example of how games have the flexibility to teach material through gameplay, in a way that is also relevant to school curricula. This discussion with the respondent also shows that engaging in a dialogue with educational experts facilitates the design process, as relevant ideas and directions can be discovered.

6.4.5 Data Literacy as an Educational Subject

The teachers interviewed highlighted that data literacy is an excellent topic to teach through a video game. This was because tasks related to sensor data and visualization such as physically gathering data and plotting graphs, takes a large amount of time and effort, and also requires specific tools. Using a game could help students get to interesting learning moments with significantly less effort. A challenge can arise where the simulation gets too simplified, which can negatively affect learning, so this must be kept in mind during design.

6.4.6 Discussion of Learning Goals

After the pilot interview, the updated learning goals were reviewed by the remaining teachers. Their impression of the goals was that they were thorough, relevant for curricula, and attainable. ”The goals are absolutely relevant to school education” T03 stated. T05 and T04 in their pair interview, noted that some of the higher level goals will be too advanced for lower grade students (8-10), but should be kept for higher grade students (11-13). T02 remarked that: ”The goals are very practically oriented”, and when asked whether this was a good thing, the teacher responded ”Definitely! Practically oriented tasks are really engaging for students, especially in more theoretical subjects like math and science.” The teachers also stated that the learning goals have clear overall relevance, and include topics relevant to various classes, such as societies, math, IT, and science. T05 noted that the goals would be even more relevant if they were to directly reference official learning objectives from the official learning plan. Because of this feedback, more emphasis was put on examining and relating to the official Norwegian learning plan documents.
The teachers suggested including learning goals about being data critical. They mentioned examples such as being able to critically reflect and understand data, detect issues with data, and being sceptical towards the use of data. One teacher stated that they would increase focus on how data could be manipulated to misinform, emphasizing how data can be used. This is useful feedback, and is another example of the wide demand for different kinds of educational games, however focusing on data criticality was deemed out of scope for Data Master.
The learning goals about visualization were overwhelmingly deemed the most relevant for school curricula by the teachers. ”The teaching plan for math includes goals about visualizing data”, respondent T02 stated, referring to the official documents describing learning goals for curricula. Excerpts from official Norwegian teaching plans can be found in the appendix (see A.2, and A.3). The goals described include visualizing data through statistics, as well as choosing between different graphs to represent data. Because the teachers were so enthusiastic about these particular learning goals, visualization was given a higher priority for the game’s design.
The Norwegian curricular learning goals are included in the appendix: A.3

Summary of Project Feedback:

- The project is interesting and relevant for education
- Accessibility is important for the game to be used

- Challenging students appropriately to their level is important
- Students are more digitally literate than before, which make games more effective teaching tools
- Teachers want access to more educational games, because they can be engaging tools
- Visualization is highly relevant for school curricula
- Data literacy is a suitable topic for an educational game
- Being data critical is a relevant topic
- Practically oriented learning is useful, and should be emphasized in the game's design
- Game concepts look interesting, and have potential

Summary of Learning Goal Feedback:

- Are practically oriented, in a good way
- Could be tailored more to school curricula - explicitly relevant
- Should focus more on the why
- Were already relevant
- Were concisely formulated
- Could include more examples
- Some goals seem too advanced for students year 8-10
- Focus on the fundamentals (which is a positive)
- Data criticality could be added

6.5 Student Interview

One student interview was conducted, and it lasted for about 25 minutes. This section discusses this interview and how it affected the project. The flyer mentioned in section 6.2.3 was also used for this interview, to help respondents understand and visualize the project.

6.5.1 Purpose

The purpose of this interview was to (1) determine interest in the game and the game concepts, (2) get feedback on the design ideas, and (3) learn more about the students' experience, with both games and data. It was also important to understand the student perspective on the project, to adapt if necessary to student expectations and ideas. Understanding the user is the core of user-centered design Dray and Siegel (2009), and although this project is not explicitly user centered it is still a valuable framework to use.

RQ1.1*: How can data literacy games be designed to be engaging for Norwegian secondary school students?*

Exploring game concepts with students allowed progress to be made towards answering this research question. The interview topics were chosen to compliment this, so some focus during the interview was on discussing game mechanics that students found engaging. Some focus was also on gauging interest in the game concepts among students. The interview plan used for this interview was discussed in section 6.2.5.

RQ1.2*: What challenges do Norwegian secondary school students face when learning data literacy?*Understanding what challenges students face when learning data literacy is important for this project. Educational games as digital tools are designed with an audience in mind, and should adapt to its audience. By helping students overcome challenges they have with learning the material, the game adds value.

RQ1.4*: What should be the learning goals for a game teaching sensor data literacy?*

This research question was not the focus of this interview, however some progress towards it was also made. Specifically gauging student experience with, and interest in the topic of data literacy was was important to understand weather the learning goals were appropriately difficult.

6.5.2 Participants

A group of 6 ninth-year students participated in the interview, 5 girls and 1 boy. The participants had some experience playing games like The Sims, and various phone and/or browser based games. In classes they had some experience using games such as a game for math with dice, and another game for geography. The usage of games in the classroom was perceived as infrequent, and students could only remember one or two instances of using educational games. They did however like games, and would have liked to use them more often for education. "It would be fun to have more games in school", one student exclaimed.

Due to girls being over-represented among student respondents, it is possible that this

skewed results, due to different preferences between girls and boys. An example of this is customization, which is a term for any game mechanic which allows the player to customize, style or change the game elements they use, often aesthetically oriented. An example is customizing the look of the player character. It is possible that customization appeals more to girls than boys, but it may also depend on the kind of customization. Future interviews should thus aim to involve more boys to ensure that their perspective is also represented in the user feedback.

6.5.3 Fun

When the students were asked what would make them interested in a game, they said that ”It should be fun”. When asked what could make a game fun, one student responded: ”Getting rewards and progressing”. Nods and other signs of approval followed this statement, by some of the other students in the group. A game being fun was the most clear and immediate feedback on how to engage students in learning. Bisson and Luckner (1996) note four central, measurable pedagogical advantages of having fun: intrinsic motivation, suspension of social reality, stress reduction, and relaxed alertness. The student's focus on fun is well supported by theory.
One student brought up the game Minecraft, as an example of a fun game that one can learn from stating: ”You can learn a lot from a game, even if it is fun”. This was an interesting statement and warranted further analysis. Firstly, the statement may indicate that many educational games are not fun to play. It is possible that some educational game creators take for granted that games as a medium is inherently fun, without understanding what makes games fun or engaging. Secondly this statement may indicate that there are games which are not made to be educational, but from which one can still learn. An advantage of using these games for education is that they are often really engaging, as developers may not have aimed at teaching, but rather at making an enjoyable game. ”You can learn a lot from Minecraft, actually.” one student states, as an example of this. From the feedback about games being fun, it is clear that educational games should ideally be as fun as regular games, or as close to this as possible, so that players are maximally engaged when playing, and therefore receptive to learning.

6.5.4 The Topic of Data Literacy

The students reported low interest in the topic of data literacy. ”It could still be fun to play at school, though”, one student exclaimed. They clarified that even if the topic was not that interesting in itself, they would still be interested in an educational game about

data literacy, especially if used in the classroom. They claimed that for them, if the game was engaging in itself, the topic did not have to be interesting for them to want to play it. The students had a low amount of experience with data collection or the use of sensors. This may indicate a need for more exposure to data and sensors, as its importance keeps growing in society.

6.5.5 Suggestions

When asked subsection other suggestions for the game, they respond that they find customization fun. Making your own character, your own city etc. and being able to see the other students' customization as well would make the game fun and engaging for them. This was then related to the game mechanics of fighting pollution in a virtual environment. One student suggested that "it would be so cool if we could visit the other student's cities (in the game), and see how they had cleaned it up". A discussion ensued, where the suggestion that the game could be about cleaning up and customizing a city, or a lake, by using sensors. Interactive ways of using such a game in class was also discussed, such as having a screen for the teacher where they could follow what students were doing in their individual games. One suggestion was displaying this on a big screen in class, so that everyone could look at each other's progress and work together or compete. Throughout this discussion, the students were engaged and interested, speaking enthusiastically. This can be seen as implicit feedback that the concepts discussed would be engaging for students. This finding is consistent with literature. Mayer (2019) observes that "Value-added research suggests five promising features to include in educational computer games: modality, personalization, pre-training, coaching, and self-explanation". Personalization and customization are in this case synonymous, showing that a promising feature from value added research is consistent with interview findings.

6.6 Results

This section will give a summary of the results of this set of interviews. The results covered include the updated list of learning goals based on feedback, as well as a brief evaluation of the interviews.

6.6.1 Data Analysis

Coding was used to analyze the qualitative data collected through he interviews. Through this process, themes emerged. These themes form the basis for the takeaways from the

interviews.

Themes

This is a list of themes emerging from data analysis:

- Accessibility for teachers
  - Ease of use
  - Easy to learn
  - Compatible (with Chrome-book)
  - Low overhead
  - Students play without help
  - Quick setup
  - Flexibly for different subjects
- Accessibility for Students
  - Adaptable difficulty
  - Apropriate level challenge
  - Smooth user experience
  - Not boring (trivial)
- Relevance
  - Curricula (math)
  - Future oriented
  - Useful
- Use of games
  - Worthwhile
  - more games needed
  - more competence needed
  - Future oriented
- Visualization
  - Math
- Game Design

  - Multiple session
  - Collaboration

The following is a discussion of the interview feedback, and the changes to the project based on the discussion.

6.6.2 Accessibility

Summarizing teacher feedback, accessibility was viewed as the most important quality in a successful DL educational game, especially for classroom settings. Central accessibility concerns mentioned by teachers include requiring little preparation and being quick and easy to use for students, which enables them to start learning quickly. Browser based games are easy to access form a technical standpoint, and students regularly use browser based tools for education. The game should also have low technical requirements, so it can run smoothly on light weight devices such as Chrome Books. This focus on accessibility is consistent with psychological literature on game learning. As discussed in section 2.4, Mayer (2016) describe that educational games should avoid extraneous processing, which comes from confusing user design. Games being more accessible, reducing the time spent on understanding or setting up the game, more learning output can come from playing the games.
Accessibility was set as a primary development goal for Data Master based on teacher feedback. There are many ways to design for accessibility. After discussion with teachers, and data analysis post interviews, a list of accessibility features was created. This list can be consulted when developers seek to add accessibility to a Data Master game.

- Browser based
- Light weight software
- Easily learnable game mechanics
- A brief player tutorial
- Quick transition from learning the game into learning about DL
- Adaptive difficulty
- User friendly interface
- Localization
- Teacher manual
- Piggybacking/footnotePiggybacking is a game design concept where designers rely on players' preexisting understanding of familiar material to facilitate teaching game concepts

6.6.3 Visualization

Among the learning goals presented to the teachers during the interview, the goals related to data visualization were unanimously considered the most relevant for class curricula. To increase relevance to curricula, focus on visualization was increased. The learning goals were expanded with additional objectives about visualization, giving this more focus in the game. This feature was originally conceptualized as a small inclusion, but after the teacher interviews it became central to the game's design. Creating game mechanics that challenge players to chose appropriate visualization methods, and allowing players to explore how to present their data for various contexts were set as goals for next design iteration.

6.6.4 Data Criticallity

When the inclusion of new elements are suggested by users, developers must some times choose between appealing to users and keeping the scope of the project lean. In many cases, adding to the scope becomes counterproductive because development resources get stretched too thin. Therefore some features may not be included in the game initially, but may be added in the event of further development. Even if a mechanic is too expensive to make initially, understanding the user demand is still important, as this informs developers of what the users expect, and allows them the insight to build the game in a way that may enable future development. Due to the focus of Data Master being on the more technical aspects of data literacy, no data criticallity was added into the game or the learning goals after the interviews, however it was added to the list of future goals for the game. It is also possible to create a separate game that tackles this issue in a more focused way, and some efforts have been put in to making games that teach players to be careful about data.

6.6.5 Student Interview Discussion and Changes

Customization was borough up as a clear positive by the students. Therefore, game designs should probe the possibility for customization if possible. If a final product of the game were to be made, it should include player customization, however this is unlikely to fit within the scope of this project. Customization is an easy feature to add, as it does not affect gameplay, and thus can be included into games without interfering with the other mechanisms of the game.
Intermediate rewards was also noted as a big positive. The game should have sub-goals that reward players on completion. One way of solving this is using achievements, another is giving players experience or currency for completing objectives. The importance of frequent rewards was mentioned by both teachers and students, and is also frequently used

in popular games to increase player engagement, so the game should aim to incorporate this.

6.6.6 Summary of Changes

- Development goal - keep the game easy to understand
- New learning goals focusing on visualization
- More focus on visualization mechanics
- Data criticallity added to list of relevant features for future work

6.6.7 Updated Learning Goals

The learning goals were updated to adapt to feedback from teachers. After the pilot interview changes were made, which were covered in the pilot interview section. After the rest of the interviews, additional changes were made to the learning goals. Here is the updated list of learning goals:

Learning Goals Iteration 4 [FINAL]

By playing a Data Master educational game, students should learn:
About what data is and how it is collected

- What data is
- What sensors are
- That sensors are used to collect data from the environment
- Why it can be important to use data to describe the environment
- Why and how to use multiple sensors
- Why and how to use sensors over time

About how to use data
Analysis

- That we can learn by analyzing data, and techniques for doing so
- Taking actions based on data: eg. reduce traffic in a polluted area
- Using data to monitor if actions are effective: eg. if reduction in traffic caused less pollution

Visualization

- How to visualize data
- That data is interpreted according to method of visualization
- How to determine appropriate visualization methods

Sensors

- How to use sensors to gather desired target data
- How to use sensors to measure data from the environment
- Why using sensors can be important

High level insights

- To compare data of different types and from different sources
- To solve problems using data
- Taking compound actions such as: Identifying data needs, selecting appropriate sensors, gathering and analyzing measurements, and taking and monitoring actions based on this data

6.6.8 Interview Evaluation

This set of interviews was a success. Valuable feedback was given to both learning goals an the project from teachers, who were enthusiastic about the project. The number of participants was higher than expected, especially among teachers, which gave a stronger impression and which results can be considered more reliable due to bigger sample size. The interview with students was brief, which made it easy to do, but the sample size could have been bigger and more varied for this interview. It was deemed most important to gain feedback from teachers on the learning goals, so these interviews were prioritized. Though the student interview could have been more compelling, the overall results were still above and beyond satisfactory.

Chapter 7

Creating A Game Design Space Document

The original plan of this project was to design and develop a data literacy (DL) educational game, however due to complications with the corona epidemic of spring 2020, this plan was altered. As interviews revealed that there was a large demand for digital literacy tools in education. Therefore a document exploring many different design options was created instead. This chapter describes the creation of this document, and the next chapter is the document itself. This game design document will be the final product of the report.

7.1 Introduction

7.1.1 What is a Game Design Document (GDD)?

A game design document (GDD) is a design blueprint of a game, that is made to facilitate the development process. Game design processes often include a GDD, however how this tool is used depends on the game. Games are as diverse a genre as one can have, and different games requires different planning, and thus different game design documents. While some game development project require hundreds of pages of specific explanation to the various teams working on everything from aesthetics, menus, sound, writing, etc. some games have simpler structure, smaller teams, and thus the need for a highly planned and detailed design document decreases.
In game development forum game dev underground (gdu.io), a forum where game designers can share and discuss ideas, an example of a more abbreviated version of a GDD was

described. This way of using GDD focuses on brevity and maintaining the design vision and direction, while leaving room to innovate, and being easy to maintain. A YouTube video on the Game Dev Underground channel discusses this approach [1]. To leave room for both smaller and larger teams to use Data Master, this approach was taken into account when exploring and creating the game design space document.

7.1.2 What is a Game Design Space Document (GDSD)?

To use a design document during the creation of a game, the document needs to be tailored to the specific needs of the project. Data Master is different in that instead of describing one particular game design in precise detail, it instead explores the space of possibility for game design in one specific niche, that being educational games for DL aimed at secondary school. At the outset of this project it was hypothesized that the potential these kinds of educational games is large, and this hypothesis seems to be supported by both the literature, and interviews with game experts, teachers, and students. The demand for educational games and digital literacy has never been greater. The GDSD is intended to contribute towards meeting this demand, by providing ideas, guidelines, and tools for designers in this field.

7.2 Iterative Design of the GDSD

A game design space document (GDSD) is a new kind of tool, which builds on the utility of the frequently used game design document (GDD) – used throughout the games industry. This document was created because the demand for educational games was exceeding that of just one game, even in the specific example of data literacy games. Being able to be more general about this topic could facilitate the creation of multiple different data literacy games, or enable the creation of a game with a bigger scope than what was possible during this project. The other reason why a GDSD document was created, was because of the Covid19 epidemic, discussed in section 1.7, which not only complicated the development of a game, but also demonstrated how important innovative digital tools are. The GDSD was created to show how the potential for data literacy educational games can be utilized in a multitude of different ways.
To explore the creation of this new kind of tool, an iterative, exploratory process was used. These iterations informed the creation of the GDSD, as well as the development process for the document. Figure 7.1 shows the iterative process. Each iteration consisted of the following:

[1] `https://www.youtube.com/watch?v=q96lz725gIw`

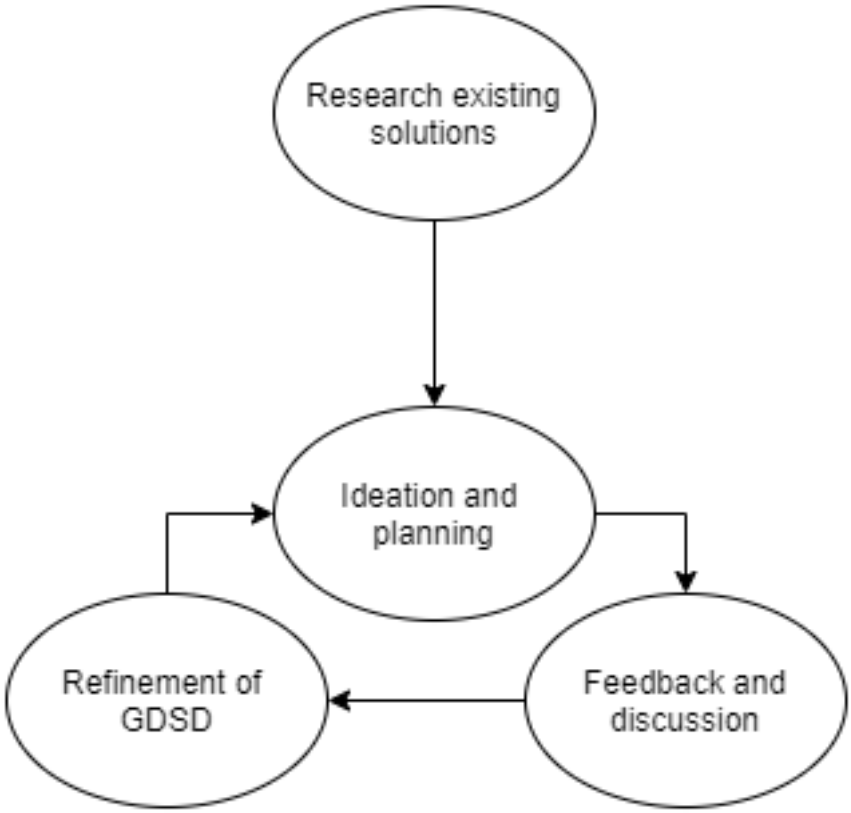


Figure 7.1: Iterative Process Diagram

1. Ideation and planning
2. Feedback and discussion with externals
3. Refinement of document based on feedback

7.2.1 Research Existing Solutions

Before the first iteration, background research was done to examine similar solutions. The primary focus was on understanding what would be helpful to designers using the GDSD to create a game. One way of understanding this was investigating the value of a GDD. However a GDD is made specifically for a game, and should thus include specific designs including all the particularities of one project. However, the GDSD aims instead to explore an array of different options, and will therefore be more broad. So copying the structure of a GDD was deemed unsatisfactory. Nevertheless, exploring how GDDs are valuable gave

an avenue of understanding what the GDSD could provide.

7.2.2 (1) Ideation and Planning

Design science is about the scientific creation of innovative artifacts, which should serve a purpose in the real world. Though this is a scientific framework, it also opens for creativity, which is necessary both when innovating and creating. The ideation and planning process involved looking through the research done in the project, and adding findings which might add value to designers. The creation and organization of the sections were created during this step, through an itreative process.

7.2.3 (2) Feedback and discussion with externals

To maintain the design quality and relevance of the document, game experts were consulted during each iteration, to provide feedback, suggestions, and advice. The experts were also interested in co-designing or discussing ideas back and forth, which was useful for the design of the document. The game experts were all people with several year experience in game design and development, with various forms of relevant higher education. For a full explanation of the interview method applied in these expert evaluations see 7.3.

7.2.4 (3) Refinement of Document Based on Feedback

After feedback was received, the document was reexamined with the feedback in mind. Some changes were easy to make, as experts had pointed out clear fixes or mistakes, such as changing the structure, including missing items, or reformulating to avoid unnecessary confusion. However other times, the feedback revealed underlying flaws with the premise of a section, or problems with a section, which was harder to adapt to. In some instances, a discussion back and forth with the expert was warranted, where each party could make suggestions, or bounce ideas back and forth.

7.3 Method — Expert Feedback

7.3.1 Participants

Here is a table of the participating experts giving feedback during the iterative process in development of the GDSD:

Game Experts Consulted		
Education	**Years of practice**	**ID**
Bachelor's Degree - Animation and Digital Arts	5	GE01
Master's Degree - Informatics	6	GE02
Game Design (1-Year)	3	GE03
Master's Degree - Informatics	6	GE04
Master's Degree - Computer Science	4	GE05

7.3.2 Questions for Rapid Iteration

Instead of doing full scale planned interviews, feedback was sought from game experts consecutively during the development process of the GDSD. This method was chosen to enable quick iteration, where changes and adaptations could be made rapidly to develop the document for final evaluation. In the early stages of development, quick feedback is often more important, as problems are more obvious. The experts were asked four questions from which to provide feedback, after the preparing statement "If you were to create a game based on this document...":

1. What should be added to the document?
2. What could be removed from the document?
3. What would you increase focus on?
4. What would you decrease focus on?

The goal was to understand what designers would like to see in a game design space document. Making experts weigh in on this was done to make the design artifact relevant for designers – for whom the document was made. The received feedback will be detailed in section 7.3.2

7.3.3 Feedback

This is a summary of feedback given during iteration on the GDSD, divided sorted by respondent ID.
Feedback from **GE01**:

- Should narrative be included? Can mechanics be tied to narrative?
- On setting, including an exploration of technology
- Clarity around the role of noise in the data, eg. wrong readings. Could a mechanic be based on this?

- Clarity on wording around pollution. Pollution could be too general of a term
- Include a description of target group, and fill out this section

Feedback from **GE02**:

- Designers may not need to see assessment, so instead of including assessment in document, link to report to understand the research foundation
- The document includes all the necessary sections to be useful
- Focus on learning should be weaved into the various parts of the document, as a through-line
- How are the mechanics designed to teach?
- The document is sufficient to start development
- Focus should be on brevity, be clear and concise over thorough and wordy

Feedback from **GE03**:

- The document seems to include necessary sections, nothing to add
- ”What is data literacy?” is the most important question, so focus on this
- Also be clear about what falls under data literacy – in general and in the project
- The ending should be brief, no need for a long summary or reflection. If a dev wants to read this they can read the report
- Data literacy initiatives, though interesting, are not that relevant for a game designer, and should thus be cut for brevity

7.3.4 Data Analysis

The structured feedback in the previous subsection came as a result of an analysis process, similar to the process described in section 6.2.8. Clarifying questions were asked to understand the teachers perspective on the document. From the analysis of data, coding was used, primarily targeting specific data. This data analysis process was also used on the feedback from evaluating the GDSD, described in 7.5. Coding was used to explore the data, and themes emerged. Some of the items listed had similar sentiments repeated by the other respondents. In some instances the respondents repeated something, and in some instances they pointed out that something was important themselves. These were examples of themes coded for when structuring the qualitative data. The structured feedback was then used in the next iteration of the document.

7.3.5 Change-Log

This is a list of changes made in chronological order, based on expert feedback:

- Added discussion of narrative, settings, and mechanics
- Added section ”target groups”
- Concepts and features rewritten to be more concise and less wordy
- ”Designing for learning” section removed, classroom relevance section added
- Rewrote definition of data literacy for clarity – useful for designers with low data literacy experience
- ”Data Literacy Initiatives” — subsection removed from 2, due to low relevance
- Added list with explanation of key skills for definition of data literacy with examples, based on feedback from GE02 about wanting to clarify what skills fall under data literacy
- Last section ”Reflection and Conclusion” changed to ”Final Thoughts”, and removed subsections for brevity
- ”Assessment of learning” subsection removed, not relevant for designers
- Full design document for of example game changed to boilerplate, with explanatory video. Video was tested with favorable results.
- Added class diagram to clarify boilerplate code. Diagram approved by expert to be in line with feedback and useful

7.4 Boilerplate Implementation

A boilerplate game implementation was made in Unity. The boilerplate was included in the GDSD as example functionality, both providing examples of how game mechanics from the document was implemented, but also adding value as a starting point for game design. The Unity engine was chosen by recommendation from Expert0 (as discussed section 5.5.2). Here the term *boilerplate* means an implementation of core components, which can be further developed into a prototype. The main reason for its development was to get some building-block functionality established, with the flexibility to be used in various game development processes. Specifically a system for having a sensor and a source of pollution in a 3d environment, and have the sensor make basic readings when in range, was implemented, which could be used in many different educational games about sensor data literacy.
The initial work done to develop a game as the product accompanying this project (see section 1.7), was re-purposed as a boilerplate implementation.

7.4.1 Video

A video was made to showcase the boilerplate. This is the description of the video:

Data Master is a Game Design Space Document (GDSD), which explores the design space around making educational games that teach data literacy. This research based document was created as a product accompanying my master thesis, and will be available online. The goal of the document, and of this boilerplate, is to help game designers make games that teach data literacy.
This video explores the open source boilerplate developed using the Unity engine. The game mechanics and implementation here are shown only as examples. The purpose of the boilerplate is to:

1. Demonstrate mechanics and concepts to discuss design ideas
2. Inspire game designers who might be interested in digitalization or data literacy
3. Give a starting point for development, with a basic system for sensors.

The boilerplate may also be useful to conduct user interviews, to give an early visual implementation. Respondents can often find it difficult to understand game mechanics from only text, so showing an implementation can therefore be useful.
This is a link to the video: `https://youtu.be/y2aeagaL-3s`

7.4.2 Evaluation of video

GE04, an Informatics master and published game designer/developer, was asked to evaluate the video. The purpose of this expert evaluation was to determine whether the video and the boilerplate were useful and relevant.
Here is a summary of the feedback (quotations are translated from Norwegian to English by the author of this report):

- ”The video was very interesting and is highly relevant for both a designer and a developer”
- ”The concept was exciting, this is actually something I could see myself experimenting with”
- It would be interesting to simulate weather such as wind, heat, precipitation, and humidity. It is good that a designer has this option, as discussed in the video
- ”The explanation of the code was a bit messy, but I understand that this is not the main point of this video”
- ”To improve this, I would have made a flowchart or unit diagram to refer to during the explanation”

There are two key takeaways from this feedback. The first is that the video was good and useful, and that the boilerplate adds value to the GDSD. The second is that a class diagram

needed to be created, to help explain the boilerplate code and add value for designers using the document. A class diagram was created based on this feedback, see figure 8.2. The designer GE04 was asked to look at the diagram, and found it a helpful addition to the document.

7.5 Evaluation of Data Master

Note: The quotes in this section have been translated from Norwegian to English by the author of this report.

Data Master was produced as the end product and design artifact of this master thesis. Though the document was created through an iterative process involving several rounds of feedback from game designers, a final evaluation was still needed for the project to claim that the document had value for designers. Two game design experts were asked to evaluate the document, GE02 and GE05.

Though this evaluation was more in depth, focus was on answering the four questions asked during the iterative process (see section 7.2.2). The method was also the same for this evaluation as for the earlier evaluation. This was chosen due to time/scope constraints, a more in-depth evaluation of the document with a bigger sample size would have been preferable.

Responding to the questions, GE02 answered that they would not add or remove anything from the document. GE05 did not want to remove anything, but was interested in the exploration of more game elements to drive engagement. ”Potentially relevant game engagement elements like *score, timer* could be interesting.” The game expert notes the inclusion of some engagement elements, such as competition and cooperation, and playfulness. ”The document is targeting general games, so some elements like scores may not be as relevant.” The elements chosen were deemed the most important and generally applicable to a wide variety of different games.

Because the feedback came after the completion of the document, no changes were made to include engaging elements like scores and timers, but these are discussed in section 9.2.3, as a suggested expansion of the document for future work.

In discussing the document, both experts claimed that it was useful. ”First impression is that it looks really good” says GE05. GE02 expressed their thoughts on the completeness of the document: ”It has all the necessary sections, it(the GDSD) covers what I would want it to cover”. The experts also found the document highly relevant as designers, which is important because relevance is a key cycle for design-science.

The document was intended mainly for game designers, though the document could also

be used for game development. About this, GE02 said: ”Though I think the document may be a bit high level to for some developers, it could be useful as a fundament for game development”. The GDSD focuses on design, but does also provide resources which could be useful in a game development process, such as an open source boilerplate implementation. GE05 stated: ”I’m particularly impressed that you have created an actual game from the ’framework’, this is really useful”. The boilerplate could aid in both the design and development process of a DL game. ”One criticism may be that it is a bit too loose/general for a game developer, although for a theoretical document this may be hard to avoid.” From this we see that the

7.5.1 summary

Although this evaluation only featured two game design experts, and was not as in depth as the evaluation presented in chapter **??**, it was appropriate given the time frame and scope of the project. The design of the document was based on research done throughout the document, and the design process used several rounds of expert feedback and evaluation. Therefore a smaller scale final evaluation was sufficient. As will be explored in the reflection, section 9.2.3, testing the use of Data Master on educational games and measure success might be good next steps for future reserach.

Chapter 8

Data Master

This is the Game Design Space Document (GDSD) titled Data Master. This document is the design artifact which was created as a product of the research done in this project. This is intended to be a standalone document, with the report as a theoretical backdrop.

Outline of this document:

- Introduction, what is this document?
- Game learning, classroom relevance, and findings
- Design Goals
- Concepts and features, sketches, design examples
- Boilerplate example game
- Final thoughts

8.1 Introduction

8.1.1 What is this Document?

Data Master is a Game Design Space Document (GDSD), with the goal of facilitating development of data literacy (DL) educational games. A game design document (GDD) is a tool used frequently during game development, to detail its design. GDDs have different

sizes and scopes depending on the project, but they often contain a vision, some design goals, and an outline of the features and components of the game (though to varying degrees of specificity). Data Master is not a GDD, which is a specific outline of the design of one game, but rather an exploration of the design space from which multiple games could be made. This document is intended to be read by game designers to facilitate the creation of DL edu games. The demand for digital tools that teach new and important skill-sets to young people is high, both in and out of schools. This GDSD aims to empower developer by providing both design ideas, and a research based foundation.

8.1.2 Background

This document was created as the product of a master of science thesis in informatics, at NTNU. The goal of this document is to facilitate developers creating DL education games. This is done by providing ideas, concepts, designs, and advice for DL game development. A full report was written detailing the research on which this document was based, and it is available upon request. The research involves: 1) a full literature review covering DL game research, 2) interviews with game design experts, teachers, and students, 3) an iterative design process. Data Master explores how to make games that teach data literacy in an engaging way, confronts challenges students face while learning, and as well as ways to increase educational relevance.

8.1.3 Target Groups

Data Master was written to primarily target secondary school students (8th-13th graders). At these years of education, classes may already involve data collection and use of both sensors and computer programs. Math classes also explore the topics of statistics and visualisation, which are important for understanding data. However data is an abstract and sometimes unfamiliar topic for students these ages, so ensuring that this important technology is accessible for these students through design is important.

8.1.4 What is Data Literacy (DL)?

This project defines data literacy as the ability to read, understand, and argue with data. This is a narrow definition, which added precision is useful for the mechanics discussed in later sections. More specifically, this project focuses primarily on sensor data, and the definition of data literacy used will therefore only include a subset of the broader data literacy toolbox. There are also some data literacy skills which are relevant to this project:

- **Collecting data** - the act of using an instrument to collect values from either the virtual or natural world, such as making a measurement with a sensor.
- **Analyzing data** - Using techniques to look at data and understand it, such as aggregation, modelling or visualizing
- **Visualizing data** - A way of presenting data analysis by making visual representations which may show the data in useful ways, such as making a bar chart
- **Using data** - using the insights gained from analyzing data or looking at visualized data, to inform decisions or solve problems, such as detecting when pollution in an area reaches a critical level

8.2 Learning Through Games

8.2.1 Game Learning

Research indicates that games have great potential to be used as educational tools. Games can offer several traits which are useful for education: engagement, immersion, novelty, specificity, and adaptability. The main challenge of designing educational game is making the game engaging, while also teaching. Playing games often involves learning how the game works and making choices based on this. Learning is therefore an essential part of gaming. The material learned from an educational game has to be useful to succeed within the game itself. Skilled players are motivated to do well by learning how the game works. Educational games should take advantage of this by teaching topics which are relevant both in and out of the game. An example of such a topic, is how to use a sensor, which some of this document's design examples explore. In this example, by learning how to use sensors in the game, the player should not only improve at the game, but also improve at using sensors in real life.

8.2.2 Classroom Relevance

Teachers have busy schedules. According to teachers interviewed, time investment, or more generally accessibility, is the most important feature gating the use of digital educational tools such as games. This must be accounted for when designing games for education. Educational games aimed at the classroom should therefore be easy to learn for both students and teachers, so they can be easily incorporated into a class without much hassle or preparation. Ideally a DL educational game is so accessible that students can play it on their own and learn, getting all the instructions needed to stat playing from the

game itself. This can be done through an intuitive and minimalist user interface, which should be tested with students to make the experience flow smoothly. To the teachers interviewed, having something that is easy to use and always works, is more valuable than something which has good learning outcomes. It is therefore important to prioritize ease of use during design.
When designing for the classroom, one must also take into account the technology available. In Norwegian secondary school classrooms, students have laptops or chrome books, which are not powerful gaming machines. Therefore, ensuring that the game is lightweight is key. Preferably the game runs in browser, for minimal setup. The game should also be set up in a way where it is easy to navigate. If a game is adaptable to different grades and levels of experience, students should be able to select their year and get an adapted experience. This flexibility which games can offer was emphasized by teachers during the interviews as an important appeal for using educational games.
In addition to this, when creating games relevant for education, it is important to consider the active curricula at secondary schools. The findings and suggestions in this document are made with official Norwegian curricula (læreplan) in mind. Educational games should look to school curricula and official learning objectives for relevance.

8.2.3 Findings

Through interviews with students and teachers, some ideas were explored which could be useful for various DL educational games. Teachers were interested in the topic of visualization, which has clear relevance to math curricula involving graphs and statistics. Considering the relevance of the material taught in an educational game is essential to increase the chances that the game might be used, especially in a classroom context. There are several ways of involving visualization in data literacy games. Teachers suggested game mechanics which centered around making players choose appropriate graphs to represent data in the game, where players would be rewarded for choosing good ways to represent the data.
Among students, a desired function was customization. Customization is used in various games, and is a flexible tool. One option is to allow aesthetic customization, which encourages a sense of ownership and personalization in the game, thus increasing engagement. Students suggested a mechanic which would allow players to customize the look of their own virtual area, such as a city. The students interviewed liked the idea of being able to show off their personalized city to other students. One option discussed for classroom integration, was to have an overview of the class displayed on the big classroom screen. Customization can be integrated in many different ways, but educational game designers

should consider designing for some form of customization in their games, as this engages students.

8.2.4 Learning Goals

Through the research project, a key task was creating a list of learning goals, i.e. objectives which the game should help players learn. The list of goals went through many revisions, after interviews with game experts and teachers. This is the final list of learning goals, which could be adapted for sensor based DL edu games:

Learning Goals Iteration 4 [FINAL]

By playing a Data Master educational game, students should learn:
About what data is and how it is collected

- What data is
- What sensors are
- That sensors are used to collect data from the environment
- Why it can be important to use data to describe the environment
- Why and how to use multiple sensors
- Why and how to use sensors over time

About how to use data
Analysis

- That we can learn by analyzing data, and techniques for doing so
- Taking actions based on data: eg. reduce traffic in a polluted area
- Using data to monitor if actions are effective: eg. if reduction in traffic caused less pollution

Visualization

- How to visualize data
- That data is interpreted according to method of visualization
- How to determine appropriate visualization methods

Sensors

- How to use sensors to gather desired target data
- How to use sensors to measure data from the environment
- Why using sensors can be important

High level insights

- To compare data of different types and from different sources
- To solve problems using data
- Taking compound actions such as: Identifying data needs, selecting appropriate sensors, gathering and analyzing measurements, and taking and monitoring actions based on this data

8.3 Design Goals

Having clear design goals makes it easier to develop game features which are aligned with a game's overall vision. Here is a list of recommended design goals:

- **Accessibility** - The game should have high ease of use from first play session, both for students and teachers. This involves an intuitive user experience, low setup and load times, clear instructions, and mechanics which are highly intuitive and learnable, even for students who lack gaming experience.

- **Engagement** - Playing a Data Master game should not feel like doing homework, but like playing an engaging game. Engagement could come from appropriate level challenge, customization, narratives, and visuals. An educational game is a game first, and should not be less exciting in the name of learning. Enable players to make choices that they find interesting, and the game will be engaging.

- **Real World Application** - Teaching data literacy through sensors is a skill for the real world. By learning how to use sensors in a game, students must therefore be able to apply what they learned to real world sensors. Being realistic where possible is therefore advised, although some stylization and simplification is often needed when adapting real world problems to the context of gameplay. Explaining how something in the game might differ from real world situations, within the game is therefore advised.

- **Feedback** - Games use feedback for communication, and feedback is also am important part of teaching. Games can offer personalized and instantaneous feedback, which gives personal attention to each student. In *The Power of Feedback*, Hattie and Timperley (2007) explains that direct praise is not as valuable for teaching, as specific feedback grounded in expectations and observations. A Data Master game should therefore aim to give feedback to players, as a central way of teaching.

8.4 Concepts and Features

During the research project upon which Data Master is based, several game concepts and features were explored, and will be detailed in this section. However the design space for DL edu games is large, and designers should use whichever ideas fit with their particular project, and do user testing. An outline of some of the explored ideas could still be useful, as concepts and features could be tweaked to fit into many different games. Design ideas could also inspire the design of other features, in an iterative process.
There are many options within the design space for teaching data literacy. To explore the design of game mechanics, Data Master focuses specifically on game concepts exploring sensor related data literacy, however there are other data literacy game projects which focus on other aspects of data literacy, such as data criticallity, personal data, or statistical analysis. The following is a list of some key concepts and mechanics which were explored during the design phase of the research project:
Realistic Sensors - Educational games aim to use gameplay to teach players something they can apply to the real world. A strong option to teach players about sensors is therefore to have realistic sensors in game, which collect data like real world sensors. By learning how to use these in-game sensors, students could then be better equipped to tackle real world data collection projects.
Virtual Environment - Sensors are tools to measure the environment, so to teach students about sensors in a game, a good option is to provide some sort of virtual environment. The virtual environment could simulate factors such as weather (eg. temperature and humidity) or pollution. The central gameplay loop would then involve collecting data from this environment. Norwegian school curricula have a cross-disciplinary goal of increasing awareness about sustainability and the environment, which might tie into the virtual environment idea as well, for added relevance.
Fighting Pollution - Because sustainability and environmental challenges are highly relevant to Norwegian school curricula, a good design option for the conflict of the game is to have players battle pollution. Because sensors are important tools to detect and counteract pollution in the real world, this setting has potential for a DL game. A game about detecting for instance air pollution near roads or a factories, or water pollution in a lake, could empower students to use sensors to detect real world pollution, in their own environments. Pollution is also a flexible threat, which could be explored in many different game design directions. One option here is to have the game center around an alarm system, where they have to detect levels of pollution, and set off alarms when a critical amount is reached in one area. This explores topics of control engineering, which are also relevant for education.

Figure 8.1: Sensor Game Design Sketches

Visualization - Because the teachers interviewed in the background research for this document were highly interested in game mechanics featuring visualization, it should always be considered in a DL edu game. One idea is to have students get challenged to select the appropriate kind of graph for data they collected in the game, or to have a data analysis step involved in the main gameplay loop. Visualization is a powerful analytical tool, to help understanding an applying data, and this could be represented in the game. Players could visualize data in order to draw conclusions about how to combat pollution in a game as well.

8.4.1 Design Sketches

Figure 8.1 shows four design ideas, sensors and data related items are drawn in red. The following is an explanation of the design concepts illustrated in this sketch:
(1) In the top right panel we see one example of using sensors, where an environment with mountains, water and trees is shown from the side. Sensors are placed at various locations, which collect data from the environment. We also see the data listed on the left, as an interface element.
(2) In the top right panel we see an illustration of how a real world sensor could interact with the game. A sensor is plugged into a tablet, where we see an overview of virtual sensors in a virtual environment, with some overlay for collected data. Using real world tools is a powerful design option to facilitate the real world applicability of what the game

teaches.
(3) In the bottom left panel we see a 3d environment with forest, road, lake and city, and an overlay with sensors and data. One concept which was also used later in the project, when developing a boilerplate implementation, was to have sensors be placed in a 3d environment, where the gameplay centered around finding good positions to place sensors and collect data.
(4) In the bottom right panel we see a still image of a natural environment, involving ocean, trees, mountains, and a parking lot to the right. Each of these locations have a pollution meter which is filling up (although pollution is only one example), and sensors are aiding in detecting the percentage of pollution. This is a more simplified interface which could draw focus more towards data analysis and visualization, instead of focusing on placing and managing sensors.

8.4.2 Competition and Cooperation

Through researching games for programming education in lower secondary school, Holst and Magnussen (2019) discovered that elements of competition or cooperation are important. Teachers were asked about these elements, and they particularly preferred game competition for games meant for one time use. Allowing for either competition or cooperation in educational games is therefore advisable, though teachers should be consulted for opinions during development.

8.4.3 Playfulness

Playfulness is also an important element for the creation of educational games, especially those targeting lower secondary school students (see report section 2.3.3). Playfulness can increase engagement, and motivation to play a game. It can also help students understand material, because they may think of it in new ways. Educational games targeting secondary school students should therefore be designed include playful elements.

8.5 Boilerplate Example Game

Along with the design ideas detailed in this document, a boilerplate implementation was made in Unity. This mainly included a system for having a sensor and a source of pollution in a 3d environment. The in-game sensor implemented was able to make basic readings when in range of pollution sources. The purpose of the boilerplate is to:

- Demonstrate mechanics and concepts to discuss design ideas

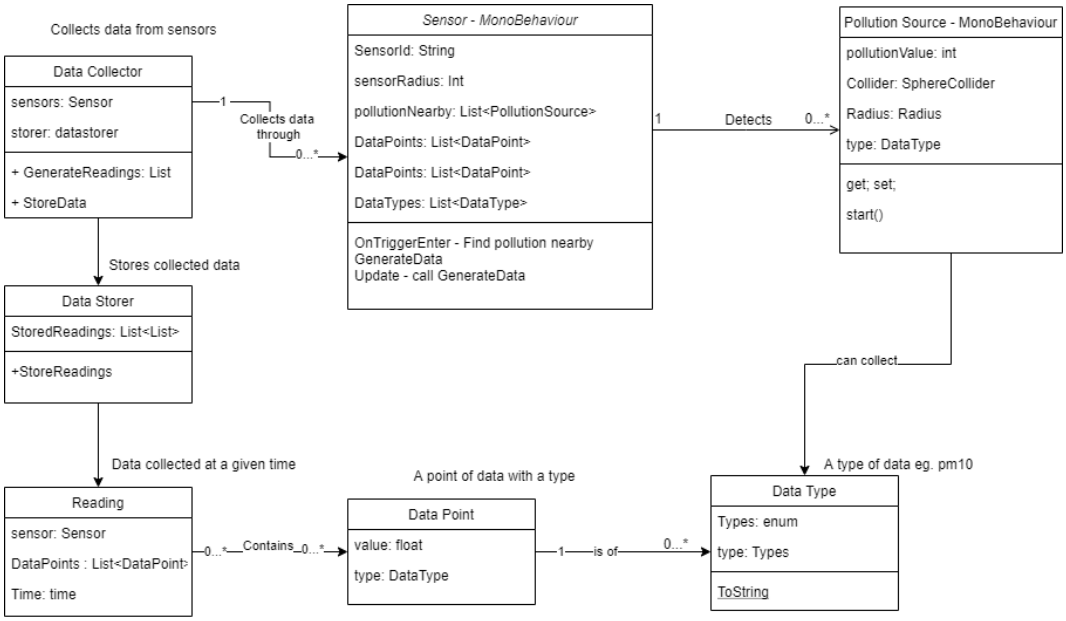


Figure 8.2: Class Diagram for Boilerplate code

- Inspire game developers who might be interested in digitalization or data literacy
- Give a starting point for development, with a basic system for sensors.

The boilerplate may also be useful to conduct user interviews, to give an early visual implementation. Respondents can often find it difficult to understand game mechanics from only text, and showing an implementation can alleviate this difficulty.
A video was made to showcase the boilerplate, giving a thorough explanation of the implementation. The video can be found here:
`https://youtu.be/y2aeagaL-3s`.
The boilerplate code is available open source:
`https://github.com/Elgeneinar/Data-Master-Unity-Boilerplate`
A class diagram was created to help developers understand the boilerplate code, shown in figure 8.2

8.6 Final Thoughts

This document has presented an overview of the design space of DL edu games. This document focuses specifically on secondary school students, and the use of sensors, but there

are many design options; findings indicate that demand for educational games is large. Making games that are relevant to the classroom involves high accessibility, which should enable teachers to include the game without hassle. Learning goals and design goals based on research were discussed, and design concepts were presented with examples, sketches, and a video. The goal of this document is to be a resource for developers of DL games. Gaining digital competence has never been more important. Data Master should be read as a strong encouragement to create innovative games that teach data skills.

Chapter 9

Conclusions

Elaboration on problem (chapter 2) Learning Goals (created chapter 4, finalized chapter 6) Game designs with expert (chapter 5)

9.1 Conclusions

The main contribution of this work is Data Master. It brings forth the knowledge of how DL edu games are designed:

- Literature Review (chapter 3)
- Teacher interviews and student interview (chapter 6)
- Boilerplate implementation and video (mentioned in chapter 7)
- Game Design Space Document — Data Master (chapter 8)

9.1.1 Research Questions

The research questions presented in section 1.2 were the foundation upon which this research was built. This section summarizes and concludes how the research questions were answered through this project.
A look at how the work relates to the research question can be found in section 6.2.1.

RQ1: How should games be designed for teaching data literacy to Norwegian secondary school students?

RQ1.1: How can data literacy games be designed to be engaging for Norwegian secondary school students?

This research has focused on understanding how to design games which teach DL to Norwegian secondary school students. The original goal of this research was to create and test a DL educational game, however due to changes presented in section 1.7, the goal became to create a GDSD instead. Data Master, the GDSD presented in chapter 8, presents an overview of important findings made throughout this research.
During the problem elaboration (chapter 2), an exploration of the importance of data, and the lack of data education in schools was made. Then an elaboration on the proposed solution to this problem ensued, which explored the importance of games as a medium, and then the possibility of using games to facilitate data literacy education.
The proposed solution looked promising, and a systematic literature review was conducted. The review investigated research around data literacy initiatives, primarily emphasizing projects using games. Various researchers had used educational DL games in their research with promising results, indicating good feasibility for the project. However the topic of sensors was not explored in the context of a DL educational games by any of the research covered in the literature review.

RQ1.2: What challenges do Norwegian secondary school students face when learning data literacy?

Both the student and teacher interviews described in chapter 6 contributed to this research question. Understanding what challenges students face can be used in a game design process to meet these challenges. Teacher interviews revealed that students must also not be bored by a game, a game than underestimates its audience is ineffective in teaching. Through the literature we have seen that students can struggle with abstract, new and digital material, such as programming, described by Holst and Magnussen (2019).

RQ1.3: What are key concerns when designing DL educational games for the classroom context?

This research question was also mainly explored during the teacher interviews described in chapter 6. Teacher interviews explored this research question by addressing concerns teachers had for the game. Accessibility was the main concern, a concern which shows up in literature as well. Being able to use games in a way is fast and easy for the teacher, this

makes the tool accessible to the classroom.
The student interviews from the same chapter also contributed towards answering this research question. The interview in part explored the students' level of experience with and interest data literacy topics. This information was used to explore what challenges might be faced in a game's design.

RQ1.4: What should be the learning goals for a game teaching sensor data literacy?

The list of learning goals included in Data Master is the answer to this research question. Based on various different sources for digital literacy requirements, learning goals were created to clarify the intended learning output of the game (see 4). This also defined what data literacy improvement looked like. Being clear about the skills intended to be improved by an educational game is essential both for its design, and for the measurement of success. The teacher interview (see section **??**).

9.2 Reflection

9.2.1 Strengths and Limitations of the Work

The document should be tested

One weakness of this work, is the lack of practical application of the GDSD. Ideally, to evaluate properly if such a document has merit, game designers should use the document in the creation of DL games and report to which degree the document was helpful. However testing the document in practice would take a lot of time, and was therefore outside the scope of this project. Though the document was created in an iterative process with expert feedback to maintain relevance, evaluation of the document could be stronger.

More student interviews

During the project, one student interview was held. This interview featured 6 ninth-year students, five females and one male. More interviews with students would make the student perspective of the project more developed, and could lead to new findings which would be useful to include in the GDSD. For further interviews, boy students should be prioritized to make up for the over-representation of girls in the first interview. For this project, having more student interviews became impossible due to the pandemic, which lead to this weakness in the work.

Research selection process for GDSD

The GDSD summarizes the research done thorough this report, focusing on the design space of DL edu games. However there were several findings which were not featured in the document. Feedback from game designers indicated a need for brevity, meaning that not all the findings could be included. Perhaps an extended GDSD could also be made, to go more in depth and include more findings.

9.2.2 Covid and demand

During the global Corona epidemic of 2020, it has never been more clear how important digital learning tools are. Schools were forced to close down to prevent the spread of the epidemic, which forced teachers to use digital media for all their teaching. The importance of having a wide range of potent digital learning tools could perhaps not be greater, and efforts should be made to strengthen the digital infrastructure in the education system. This project has explored how games can be used to teach data literacy, which is the use of digital tools to increase digital literacy. Both the topic, and the method focus on improving the potency and use of digital tools. The project delved into the question of how these tools can be developed. With the increase in digital demand caused by the epidemic, this has revealed more than ever the need for digital innovation in the educational system. Research in this area may therefore be important in this time.

9.2.3 Recommendations for Future Work

One interesting suggestion for future work would be to see Data Master used as a fundament for the creation of DL games. Though some evaluation was done for the GDSD, much could be learned from having it used in practice. The data from game projects using Data Master could also be useful for expanding the GDSD, which is another possibility for future work. During the final evaluation, the inclusion of more engagement element such as scores and timers was suggested (see 7.5). Though their omission may broaden the pool of potential games made using the document, there could also be added value by including these elements as suggestions in the GDSD.
Anther recommendation for future work was suggested by GE05, citing Houben et al. (2016). The article describes the authors' approach: "We propose a 'human-data design' approach in which end-users are given tools to create, share, and use data through tangible and physical visualizations". Combining the *human-data design* approach and have students design games using based on the findings presented in the GDSD would also be an interesting focus for future work.

Bibliography

Anderson, E. F., Engel, S., McLoughlin, L., and Comninos, P. (2008). The case for research in game engine architecture. *ACM Future Play 2008 International Academic Conference on the Future of Game Design and Technology, Future Play: Research, Play, Share*, pages 228–231.

Bertelsen, O. W. (2000). Design Artifacts. *Scandinavian Journal of Information Systems*, 12(1):15–28.

Bhargava, R. and Ignazio, C. D. (2015). Designing Tools and Activities for Data Literacy Learners. *Workshop on Data Literacy*, pages 1–5.

Bhargava, R., Kadouaki, R., Bhargava, E., Castro, G., and D'Ignazio, C. (2016). Data Murals: Using the Arts to Build Data Literacy. *Journal of Community Informatics*, 12(3):197–216.

Bisson, C. and Luckner, J. (1996). Fun in Learning: The Pedagogical Role of Fun in Adventure Education. *Journal of Experiential Education*, 19(2):108–112.

Carretero, S., Vuorikari, R., and Punie, Y. (2017). *DigComp 2.1: The Digital Competence Framework for Citizens. With eight proficiency levels and examples of use*.

Deahl, E. S. (2014). Better the Data You Know: Developing Youth Data Literacy in Schools and Informal Learning Environments. *SSRN Electronic Journal*.

DOMO (2020). Data Never Sleeps 7.0. Technical report.

Donoho, D. (2017). 50 Years of Data Science.

Dray, S. M. and Siegel, D. A. (2009). Understanding users in context: An in-depth introduction to fieldwork for user centered design. In Gross, T., Gulliksen, J., Kotzé, P., Oestreicher, L., Palanque, P., Prates, R. O., and Winckler, M., editors, *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, volume 5727 LNCS, pages 950–951, Berlin, Heidelberg. Springer Berlin Heidelberg.

Flick, U., Von Kardoff, E., and Steinke, I. (2004). *A Companion to Qualitative Research*.

Gäbler, J., Winkler, C., Lengyel, N., Aigner, W., Stoiber, C., Wallner, G., and Kriglstein, S. (2019). Diagram safari: A visualization literacy game for young children. *CHI PLAY 2019 - Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play*, pages 389–396.

Gibbs, G. R. (2018). *Analysing Qualitative Data*. 2nd edition.

Grillenberger, A. and Romeike, R. (2019). About Classes and Trees: Introducing Secondary School Students to Aspects of Data Mining. pages 147–158.

Guo, Y. R. and Goh, D. H. L. (2016). From storyboard to software: User evaluation of an information literacy game. *Proceedings of the ACM Symposium on Applied Computing*, 04-08-Apri:199–201.

Hattie, J. and Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, 77(1):81–112.

Hevner, A. R. (2007). A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*.

Hevner, A. R., March, S. T., Park, J., and Ram, S. (2004). Design science in information systems research. *MIS Quarterly: Management Information Systems*, 28(1):75–105.

Holst, A. and Magnussen, M. (2019). *Code Flip: A Game for the Norwegian Elective Course of Programming [MCs thesis]*.

Houben, S., Golsteijn, C., Gallacher, S., Johnson, R., Bakker, S., Marquardt, N., Capra, L., and Rogers, Y. (2016). Physikit: Data engagement through physical ambient visualizations in the home. *Conference on Human Factors in Computing Systems - Proceedings*, pages 1608–1619.

Jonson, B. (2005). Design ideation: The conceptual sketch in the digital age. *Design Studies*, 26(6):613–624.

Kajornboon, A. B. (2005). Using interviews as research instruments Annabel Bhamani Kajornboon Language Institute Chulalongkorn University. *E-journal for Research Teachers*, 2(1).

Koltay, T. (2015). Data literacy: In search of a name and identity. *Journal of Documentation*, 71(2):401–415.

Koltay, T. (2017). Data literacy for researchers and data librarians.

Loukides, M. K. (2012). *What is Data Science?* O'Reilly Media; 1 edition (April 10, 2011).

Magnussen, M. and Holst, A. (2018). Games for Programming: Targeting the Elective Programming Course of Norwegian Lower Secondary Schools.

Maneth, S. and Poulovassilis, A. (2017). Data science.

Mayer, R. E. (2016). What Should Be the Role of Computer Games in Education? *Policy Insights from the Behavioral and Brain Sciences*.

Mayer, R. E. (2019). Computer Games in Education. *Annual Review of Psychology*, 70(1):531–549.

Rouse, R. (2014). Game design. In *The Routledge Companion to Video Game Studies*, pages 83–90. Taylor and Francis.

Schield, M. (2004). Information Literacy , Statistical Literacy and Data Literacy. *IASSIST Quarterly*, (6):6–11.

Schutt, R. and O'Neil C. (2013). *Doing Data Science*.

Smuts, A. (2005). Are Video Games Art? *Contemporary Aesthetics*, 3(1):6.

Spikol, D. and Milrad, M. (2008). Combining physical activities and mobile games to promote novel learning practices. *Proceedings - 5th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education, WMUTE 2008*, pages 31–38.

Squire, K. (2003). Video games and education. *Computers in Entertainment*, 1(1):10.

Vahey, P., Rafanan, K., Patton, C., Swan, K., van 't Hooft, M., Kratcoski, A., and Stanford, T. (2012). A cross-disciplinary approach to teaching data literacy and proportionality. *Educational Studies in Mathematics*, 81(2):179–205.

Vahey, P., Yarnall, L., and Patton, C. (2006). Mathematizing middle school: Results from a cross-disciplinary study of data literacy. *American Educational Research Association Annual Conference*, pages 1–15.

Webb, K. (2019). The $120 billion gaming industry is going through more change than it ever has before, and everyone is trying to cash in.

Whitton, N. (2011). Game engagement theory and adult learning. *Simulation and Gaming*, 42(5):596–609.

Williams, S., Deahl, E., Rubel, L., and Lim, V. (2014). City Digits: Local Lotto: Developing Youth Data Literacy by Investigating the Lottery — Journal of Digital and Media Literacy. *Journal of Digital and Media Literacy*, pages 1–16.

Wolff, A., Gooch, D., Cavero Montaner, J., Rashid, U., and Kortuem, G. (2017). Creating an understanding of data literacy for a data-driven society. *Journal of Community Informatics*, 12(3):(In press).

Wolff, A. and Kortuem, G. (2015). Visualising energy: teaching data literacy in schools. *Sencity 2*.

Wolff, A., Kortuem, G., and Cavero, J. (2015). Urban data games: Creating smart citizens for smart cities. *Proceedings - IEEE 15th International Conference on Advanced Learning Technologies: Advanced Technologies for Supporting Open Access to Formal and Informal Learning, ICALT 2015*, pages 164–165.

Wong, C. (2009). Kids ' Survey Network : Teaching Data Literacy with Multiplayer Online Games by.

Zirawaga, Victor Samuel—Olusanya, A. I. T. (2017). Gaming in Education: Using Games as a Support Tool to Teach History. *Journal of Education and Practice*, 8(15):55–64.

Appendix A

Appendix Chapter Name

A.1 Flyer

This is the flyer used during the interviews in chapter 6:

DataMaster

Spillet som lærer elevene hva data er, og hvordan den kan brukes

Utforsk med sensorer

Bruk fysiske og virtuelle sensorer til å utforske hva man kan gjøre med data. Gjør målinger og vurder dataen, for å bekjempe luftforurensning!

Ved å spille dette spillet blir elevene utfordret til å finne ut hvordan de kan bruke sensorer til å forstå miljøet rundt dem. Spillet er rettet mot bærekraftsmål, og handler om å detektere og bekjempe forurensning. Å forstå data blir viktigere og viktigere i samfunnet. Ved å håndtere realistiske datarelaterte problemstillinger blir elevene rustet til å kunne bruke data.

Lars Møster
Master Informatikk NTNU
94237502
lars.moster@hotmail.com

A.2 Norwegian Cross-Disciplinary Values

kulturelle uttrykk, og de bidrar til å løfte fram nye perspektiver. Kunst- og kulturuttrykk har også betydning for den enkeltes personlige utvikling. Kulturelle opplevelser har en egenverdi, og elevene skal få oppleve et variert spekter av kulturuttrykk gjennom sin tid i skolen.

I et større perspektiv er skapende læringsprosesser også en forutsetning for elevenes danning og identitetsutvikling. Skolen skal verdsette og stimulere elevenes vitebegjær og skaperkraft, og elevene skal få bruke sine skapende krefter gjennom hele grunnopplæringen.

1.5 Respekt for naturen og miljøbevissthet

Skolen skal bidra til at elevene utvikler naturglede, respekt for naturen og klima- og miljøbevissthet.

Mennesket er en del av naturen og har ansvar for å forvalte den på en forsvarlig måte. Gjennom opplæringen skal elevene få kunnskap om og utvikle respekt for naturen. De skal få oppleve naturen og se den som en kilde til nytte, glede, helse og læring. Elevene skal utvikle bevissthet om hvordan menneskets levesett påvirker naturen og klimaet, og dermed også våre samfunn. Skolen skal bidra til at elevene utvikler vilje til å ta vare på miljøet.

Barn og unge skal håndtere dagens og morgendagens utfordringer, og vår felles framtid avhenger av at kommende generasjoner tar vare på kloden. Globale klimaendringer, forurensning og tap av biologisk mangfold er blant de største miljøtruslene i verden. Disse utfordringene må løses i fellesskap. Vi behøver kunnskap, etisk bevissthet og teknologisk innovasjon for å finne løsninger og gjøre nødvendige endringer i levesettet vårt for å ta vare på livet på jorda.

1.6 Demokrati og medvirkning

Skolen skal gi elevene mulighet til å medvirke og til å lære hva demokrati betyr i praksis.

Opplæringen skal fremme oppslutning om demokratiske verdier og demokratiet som styreform. Den skal gi elevene forståelse for demokratiets spilleregler og betydningen av å holde disse i hevd. Å delta i samfunnet innebærer å respektere og slutte opp om grunnleggende demokratiske verdier som gjensidig respekt, toleranse, den enkeltes tros- og ytringsfrihet og frie valg. Demokratiske verdier må fremmes gjennom aktiv deltakelse i hele opplæringsløpet.

Skolen skal fremme demokratiske verdier og holdninger som motvekt mot fordommer og diskriminering. Skolen skal også skape respekt for at mennesker er forskjellige, og elevene

det å kunne lese avanserte faglige tekster.

I undervisningen må de grunnleggende ferdighetene ses både i sammenheng med hverandre og på tvers av fag. De grunnleggende ferdighetene hører hjemme i alle fag, men fagene spiller ulike roller i utviklingen av de forskjellige ferdighetene. Enkelte fag vil ha et større ansvar enn andre. Utvikling av faglig kompetanse skal derfor skje i samspill med utviklingen av grunnleggende ferdigheter i faget slik det er beskrevet i læreplanene for fagene. Lærere i alle fag skal støtte elevene i arbeidet med grunnleggende ferdigheter.

2.4 Å lære å lære

Skolen skal bidra til at elevene reflekterer over sin egen læring, forstår sine egne læringsprosesser og tilegner seg kunnskap på selvstendig vis.

Når elevene forstår sine egne læringsprosesser og sin faglige utvikling, bidrar det til selvstendighet og mestringsfølelse. Opplæringen skal fremme elevenes motivasjon, holdninger og læringsstrategier, og legge grunnlaget for læring hele livet. Det krever at lærerne følger elevenes utvikling tett og gir dem støtte tilpasset deres alder, modenhets- og funksjonsnivå.

Ved å reflektere over egen og andres læring kan elever litt etter litt utvikle bevissthet om egne læringsprosesser. Elever som lærer å formulere spørsmål, søke svar og uttrykke sin forståelse på ulike måter, vil gradvis kunne ta en aktiv rolle i egen læring og utvikling. Gjennom arbeid med faglige utfordringer vil elevene få kunnskap om hvordan de lærer og utvikler seg i faget. Dypere innsikt utvikles når elevene ser sammenhenger mellom kunnskapsområder, og når de behersker et mangfold av strategier for å tilegne seg, dele og forholde seg kritisk til kunnskap.

Til tross for elevenes egeninnsats og bruk av læringsstrategier vil enkelte ha utfordringer med å lære. Årsakene er ofte mange og sammensatte. Ambisjonen om å utvikle evnen til livslang læring hos alle elever krever derfor en bred tilnærming fra skolen.

2.5 Tverrfaglige temaer

Skolen skal legge til rette for læring innenfor de tre tverrfaglige temaene folkehelse og livsmestring, demokrati og medborgerskap, og bærekraftig utvikling.

De tre tverrfaglige temaene i læreplanverket tar utgangspunkt i aktuelle samfunnsutfordringer som krever engasjement og innsats fra enkeltmennesker og fellesskapet i lokalsamfunnet, nasjonalt og globalt. Elevene utvikler kompetanse knyttet til de tverrfaglige temaene gjennom arbeid med problemstillinger fra ulike fag. Elevene skal få innsikt i utfordringer og dilemmaer innenfor temaene. De skal forstå hvordan vi gjennom kunnskap og samarbeid kan finne løsninger, og de skal lære om sammenhenger mellom handlinger og konsekvenser.

Kunnskapsgrunnlaget for å finne løsninger på problemer innenfor temaene finnes i mange fag, og temaene skal bidra til at elevene oppnår forståelse og ser sammenhenger på tvers av fag. Målene for hva elevene skal lære innenfor temaene, uttrykkes i kompetansemål for fag der det er relevant.

2.5.1 Folkehelse og livsmestring

Folkehelse og livsmestring som tverrfaglig tema i skolen skal gi elevene kompetanse som fremmer god psykisk og fysisk helse, og som gir muligheter til å ta ansvarlige livsvalg. I barne- og ungdomsårene er utvikling av et positivt selvbilde og en trygg identitet særlig avgjørende.

Et samfunn som legger til rette for gode helsevalg hos den enkelte, har stor betydning for folkehelsen. Livsmestring dreier seg om å kunne forstå og å kunne påvirke faktorer som har betydning for mestring av eget liv. Temaet skal bidra til at elevene lærer å håndtere medgang og motgang, og personlige og praktiske utfordringer på en best mulig måte.

Aktuelle områder innenfor temaet er fysisk og psykisk helse, levevaner, seksualitet og kjønn, rusmidler, mediebruk, og forbruk og personlig økonomi. Verdivalg og betydningen av mening i livet, mellommenneskelige relasjoner, å kunne sette grenser og respektere andres, og å kunne håndtere tanker, følelser og relasjoner hører også hjemme under dette temaet.

2.5.2 Demokrati og medborgerskap

Demokrati og medborgerskap som tverrfaglig tema i skolen skal gi elevene kunnskap om demokratiets forutsetninger, verdier og spilleregler, og gjøre dem i stand til å delta i demokratiske prosesser. Opplæringen skal gi elevene forståelse for sammenhengen mellom demokrati og sentrale menneskerettigheter som ytringsfrihet, stemmerett og organisasjonsfrihet. De skal få innsikt i at demokratiet har ulike former og uttrykk.

Gjennom arbeid med temaet demokrati og medborgerskap skal elevene forstå

sammenhengen mellom individets rettigheter og plikter. Individene har rett til å delta i politisk arbeid, samtidig som samfunnet er avhengig av at borgerne bruker rettighetene til politisk deltakelse og utforming av det sivile samfunnet. Skolen skal stimulere elevene til å bli aktive medborgere, og gi dem kompetanse til å delta i videreutviklingen av demokratiet i Norge.

Opplæringen skal gi elevene kunnskaper og ferdigheter til å møte utfordringer i tråd med demokratiske prinsipper. De skal forstå dilemmaer som ligger i å anerkjenne både flertallets rett og mindretallets rettigheter. De skal øve opp evnen til å tenke kritisk, lære seg å håndtere meningsbrytninger og respektere uenighet. Gjennom arbeidet med temaet skal elevene lære hvorfor demokratiet ikke kan tas for gitt, og at det må utvikles og vedlikeholdes.

2.5.3 Bærekraftig utvikling

Bærekraftig utvikling som tverrfaglig tema i skolen skal legge til rette for at elevene kan forstå grunnleggende dilemmaer og utviklingstrekk i samfunnet, og hvordan de kan håndteres. Bærekraftig utvikling handler om å verne om livet på jorda og å ta vare på behovene til mennesker som lever i dag, uten å ødelegge framtidige generasjoners muligheter til å dekke sine behov. En bærekraftig utvikling bygger på forståelsen av sammenhengen mellom sosiale, økonomiske og miljømessige forhold. Menneskehetens levesett og ressursbruk har konsekvenser lokalt, regionalt og globalt.

Gjennom arbeid med temaet skal elevene utvikle kompetanse som gjør dem i stand til å ta ansvarlige valg og handle etisk og miljøbevisst. Elevene skal få forståelse for at handlingene og valgene til den enkelte har betydning. Temaet rommer problemstillinger knyttet til miljø og klima, fattigdom og fordeling av ressurser, konflikter, helse, likestilling, demografi og utdanning. Elevene skal lære om sammenhengen mellom de ulike aspektene ved bærekraftig utvikling.

Teknologi har betydelig innvirkning på menneske, miljø og samfunn. Teknologisk kompetanse og kunnskap om sammenhengene mellom teknologi og de sosiale, økonomiske og miljømessige sidene ved bærekraftig utvikling står derfor sentralt i dette temaet. Teknologiutvikling kan bidra til å løse problemer, men kan også skape nye. Kunnskap om teknologi innebærer en forståelse av hvilke dilemmaer som kan oppstå ved bruk av teknologi, og hvordan disse kan håndteres.

3. Prinsipper for skolens praksis

Skolen skal møte elevene med tillit, respekt og krav, og de skal få utfordringer som fremmer

danning og lærelyst. For å lykkes med dette må skolen bygge et godt læringsmiljø og tilpasse undervisningen i samarbeid med elevene og hjemmene. Det krever et profesjonsfellesskap som engasjerer seg i skolens utvikling.

3.1 Et inkluderende læringsmiljø

Skolen skal utvikle inkluderende fellesskap som fremmer helse, trivsel og læring for alle.

Et raust og støttende læringsmiljø er grunnlaget for en positiv kultur der elevene oppmuntres og stimuleres til faglig og sosial utvikling. Føler elevene seg utrygge, kan det hemme læring. Trygge læringsmiljøer utvikles og opprettholdes av tydelige og omsorgsfulle voksne, i samarbeid med elevene. De ansatte på skolen, foreldre og foresatte og elevene har sammen ansvar for å fremme helse, trivsel og læring, og for å forebygge mobbing og krenkelser. I arbeidet med å utvikle et inkluderende og inspirerende læringsmiljø skal mangfold anerkjennes som en ressurs.

Elevmedvirkning må prege skolens praksis. Elevene skal både medvirke og ta medansvar i læringsfellesskapet som de skaper sammen med lærerne hver dag. Elever tenker, erfarer og lærer i samspill med andre gjennom læringsprosesser, kommunikasjon og samarbeid. Skolen skal lære elevene å utvise dømmekraft når de ytrer seg om andre, og sørge for at de lærer å samhandle på forsvarlig vis i ulike sammenhenger.

De normene og verdiene som preger læringsfellesskapet, har stor betydning for elevenes sosiale utvikling. Vennskap skaper tilhørighet og gjør oss alle mindre sårbare. Når vi selv opplever å bli anerkjent og vist tillit, lærer vi å verdsette både oss selv og andre. Elevene skal lære å respektere forskjellighet og forstå at alle har en plass i fellesskapet. Hver elev har en historie med seg, og de har håp og ambisjoner for framtiden. Når barn og unge møter respekt og anerkjennelse i opplæringen, bidrar dette til en opplevelse av tilhørighet.

Ved å bruke varierte læringsarenaer kan skolen gi elevene praktiske og livsnære erfaringer som fremmer motivasjon og innsikt. Lokalmiljøets og samfunnets engasjement kan bidra positivt til skolens og elevenes utvikling. Ulike former for lokalt, nasjonalt og internasjonalt samarbeid forankrer elevenes læring i aktuelle spørsmål. Kunnskapsutveksling med mennesker i alle aldre og fra ulike steder i verden gir elevene perspektiver på egen læring, danning og identitet og viser verdien av samarbeid på tvers av språklige, politiske og kulturelle grenser.

3.2 Undervisning og tilpasset opplæring

Skolen skal legge til rette for læring for alle elever og stimulere den enkeltes motivasjon, lærelyst og tro på egen mestring.

Elevenes læring og utvikling skal stå i sentrum for skolens virksomhet. Elevene møter skolen med ulike erfaringer, forkunnskaper, holdninger og behov. Skolen må gi alle elever likeverdige muligheter til læring og utvikling, uavhengig av deres forutsetninger. God klasseledelse bygger på innsikt i elevenes behov, varme relasjoner og profesjonell dømmekraft. For å skape motivasjon og læringsglede i undervisningen trengs et bredt repertoar av læringsaktiviteter og -ressurser innenfor forutsigbare rammer.

Skolens forventninger til den enkelte elev om innsats og mestring påvirker læring og tro på egne evner og muligheter. Det er derfor avgjørende at skolen møter alle elever med ambisiøse, men realistiske forventninger, og at lærere utviser et profesjonelt skjønn når de vurderer elevenes læring.

Elevene skal få tid til å utforske dybden i ulike fagområder. Å gi rom for dybdelæring forutsetter at skolen tar hensyn til at elevene er forskjellige og lærer i ulikt tempo og med ulik progresjon. Det krever kunnskap om hvordan elever lærer, hva de kan fra før, og forutsetter tett oppfølging av den enkelte. Elever som opplever mestring, motiveres til å bli mer utholdende og selvstendige. Prøving og feiling kan være en kilde til læring og erkjennelse, og elevene skal oppfordres til å prøve seg også når det er usikkert om de vil lykkes. Det er skolens oppgave å gi elevene trygghet til å krysse grenser og prøve noe vanskelig.

Vurderingen av elevenes faglige kompetanse skal gi et bilde av hva elevene kan, men et sentralt formål med vurderingen er også å fremme læring og utvikling. Kartlegging og observasjon av elevene er virkemidler for å følge opp den enkelte og for utvikling av skolens praksis. Det har imidlertid liten verdi dersom det ikke følges opp med konstruktive tiltak. Skolen og lærerne må balansere behovet for god informasjon om elevenes læring og uønskede konsekvenser av ulike vurderingssituasjoner. Uheldig bruk av vurdering kan svekke den enkeltes selvbilde og hindre utviklingen av et godt læringsmiljø.

Tilpasset opplæring er tilrettelegging som skolen gjør for å sikre at alle elever får best mulig utbytte av den ordinære opplæringen. Skolen kan blant annet tilpasse opplæringen gjennom arbeidsformer og pedagogiske metoder, bruk av læremidler, organisering, og i arbeidet med læringsmiljøet, læreplaner og vurdering. Lærerne må bruke et godt faglig skjønn i arbeidet med å tilpasse opplæringen.

God vurdering, der forventningene er tydelige og eleven deltar og blir hørt underveis i læringsarbeidet, er en nøkkel til å tilpasse undervisningen. Lærerne skal i sin undervisning støtte og veilede elevene til å kunne sette seg mål, velge egnede framgangsmåter og vurdere sin egen utvikling. Skolen må planlegge for en god sammenheng i elevenes læring i de ulike fagene og for at opplæringen oppleves som både overkommelig og tilstrekkelig utfordrende.

Tilpasset opplæring gjelder alle elever, og skal i størst mulig grad skje gjennom variasjon og

tilpasninger til mangfoldet i elevgruppen innenfor fellesskapet. Elever som har behov for tilrettelegging utover det ordinære tilbudet, har krav på spesialundervisning. Elever kan streve, og det kan oppstå ulike problemer med å lære gjennom hele opplæringsløpet. Lærerne kan få god støtte fra andre yrkesgrupper både til å avdekke utfordringer og til å gi elevene den hjelpen de trenger. Det kan være av avgjørende betydning for elevens utvikling at tiltak settes inn så raskt som mulig når utfordringene oppdages.

3.3 Samarbeid mellom hjem og skole

Opplæringen skal skje i samarbeid og forståelse med hjemmet, og samarbeidet skal bidra til å styrke elevenes læring og utvikling.

God kommunikasjon mellom hjem og skole bidrar positivt til skolens arbeid med læringsmiljøet og til elevenes oppvekstmiljø. Foreldrene og foresatte har hovedansvaret for barnets oppdragelse og utvikling. De er barnas og ungdommenes viktigste omsorgspersoner og har kunnskap som skolen kan bruke for å støtte elevens danning, læring og utvikling. Skolen har det overordnede ansvaret for å ta initiativet til og tilrettelegge for samarbeid. Dette innebærer å sørge for at foreldre og foresatte får nødvendig informasjon, og for at de gis mulighet til å ha innflytelse på sine barns skolehverdag.

Hjemmets holdning til skole er av stor betydning for elevenes engasjement og skoleinnsats. Foreldre og foresatte møter skolen med ulike behov, forventninger og meninger om skolens mål og praksis. Det kan skape spenninger som kan være krevende for skolen å håndtere. Skolen må gi tydelig uttrykk for hva den skal og kan tilby, og hva som forventes av hjemmet. God og tillitsfull dialog er et gjensidig ansvar. Skolen må imidlertid ta hensyn til at ikke alle elever har samme mulighet til å få hjelp og støtte i hjemmet.

3.4 Opplæring i lærebedrift og arbeidsliv

Opplæring i lærebedrift og arbeidsliv skal gi praktisk erfaring og relevant kompetanse, og forberede på de faglige kravene og forventningene som stilles i arbeidslivet.

Opplæring i lærebedrift er en del av opplæringsløpet til lærlinger, lærekandidater og praksisbrevkandidater. I tillegg vil mange elever i løpet av grunnopplæringen få deler av opplæringen i arbeidslivet. Fag- og yrkesopplæringen skal danne og utdanne dyktige,

A.3 Norwegian Math Curricula Learning Goals

A.3.1 8th - 10th grade

Kompetansemål etter 8. trinn

Mål for opplæringa er at eleven skal kunne

- bruke potensar med heiltalig eksponent og kvadratrøter i utforsking og problemløysing og argumentere for framgangsmåtar og resultat
- utvikle og kommunisere strategiar for hovudrekning i utrekningar
- utforske og beskrive primtalsfaktorisering og bruke det i brøkrekning
- utforske grunnleggjande algebraiske rekneregler
- beskrive og generalisere mønster med eigne ord og algebraisk
- lage rekneuttrykk til praktiske situasjonar og finne praktiske situasjonar som passar til oppgitte rekneuttrykk med tal, variablar og konstantar
- utforske, beskrive og samanlikne funksjonar i praktiske situasjonar
- representere funksjonar på ulike måtar og vise samanhengar mellom representasjonane
- lage og løyse likningar knytte til praktiske situasjonar og finne praktiske situasjonar som passar til likningar
- utforske likskapar og ulikskapar mellom måleiningane til urfolk og måleiningane til andre kulturar
- utforske korleis algoritmar kan skapast, testast og forbetrast ved hjelp av programmering

Kompetansemål etter 9. trinn

Mål for opplæringa er at eleven skal kunne

- beskrive, forklare og presentere struktur og utviklingar i geometriske mønster og i talmønster
- forklare omgrepa formlikskap og kongruens og bruke dei i resonnering og rekning med polygon
- analysere eigenskapane ved polygon og gjere utrekningar knytte til slike figurar
- utforske, beskrive og argumentere for samanhengar mellom sidelengdene i trekantar
- tolke og lage arbeidsteikningar etter målestokk
- beskrive og argumentere for samanhengen mellom radius og areal i ein sirkel
- endre føresetnader i geometriske problemstillingar og argumentere for korleis det påverkar løysingane
- utforske, forklare og bruke geometriske stader i praktiske situasjonar
- utforske og argumentere for formlar for overflateareal og volum av tredimensjonale figurar
- formulere og løyse problem knytte til samansette måleiningar
- planleggje, utføre og presentere eit utforskande arbeid knytt til personleg økonomi
- bruke programmering til å utforske matematiske eigenskapar og samanhengar

Kompetansemål etter 10. trinn

Mål for opplæringa er at eleven skal kunne

- utforske og generalisere multiplikasjon av polynom algebraisk og geometrisk
- bruke digitale verktøy til å utforske og samanlikne eigenskapar til ulike funksjonar
- rekne ut stigingstalet til ein lineær funksjon og bruke det til å forklare omgrepa endring per eining og gjennomsnittsfart
- utforske samanhengen mellom konstant prosentvis endring, vekstfaktor og eksponentialfunksjonar
- lage og løyse likningssett knytte til praktiske situasjonar og finne praktiske situasjonar som passar til likningssett
- bruke funksjonar i modellering og argumentere for framgangsmåtar og resultat
- hente ut og tolke relevant informasjon frå tekster om kjøp og sal og ulike typar lån og bruke det til å formulere og løyse problem
- tolke og kritisk vurdere statistiske framstillingar frå media og lokalsamfunnet
- modellere situasjonar knytte til populasjonar, presentere resultata og argumentere for at modellen er gyldig

A.3.2 Practical Math (year 11-12)

Kompetansemål etter matematikk 1P

Mål for opplæringa er at eleven skal kunne

- vurdere val knytte til økonomi og kunne reflektere over konsekvensar ved å ta opp lån og bruke kredittkort
- analysere og presentere funn i datasett frå lokalsamfunn og media
- bruke og vurdere val av formålstenlege sentralmål og spreiingsmål for statistisk datamateriale
- lese, hente ut og vurdere matematikk i tekstar knytte til situasjonar frå lokalmiljøet, gjere berekningar knytte til dette og presentere og argumentere for resultata
- utforske korleis ulike premissar vil kunne påverke korleis matematiske problem frå samfunnsliv og yrkesliv blir løyste
- modellere situasjonar knytte til tema frå samfunnsliv og arbeidsliv, presentere og argumentere for resultata og kor tid modellen er gyldig
- identifisere variable storleikar i ulike situasjonar og bruke dei til utforsking og generalisering
- tolke og bruke formlar som gjeld samfunnsliv og arbeidsliv
- bruke prosent, prosentpoeng, promille og vekstfaktor i utrekningar og presentere og grunngi løysingar
- utforske, beskrive og bruke omgrepa proporsjonalitet og omvend proporsjonalitet
- tolke og bruke samansette måleiningar i praktiske samanhengar og velje eigna måleining
- utforske og forklare korleis formlikskap, målestokk og eigenskapar ved geometriske figurar kan brukast i berekningar og i praktisk arbeid

Kompetansemål

Mål for opplæringa er at eleven skal kunne

- tolke og bruke funksjonar i matematisk modellering og problemløysing
- planleggje, utføre og presentere sjølvstendig arbeid knytt til modellering og funksjonar i samfunnsfaglege tema
- bruke digitale verktøy i utforsking og problemløysing knytt til eigenskapar ved funksjonar, og diskutere løysingane
- tolke og rekne med rotuttrykk, potensar og tal på standardform
- forklare og bruke prosent, prosentpoeng og vekstfaktor til modellering av praktiske situasjonar med digitale verktøy
- utforske og forklare samanhengar mellom prisindeks, kroneverdi, reallønn, nominell lønn og brutto- og nettoinntekt
- utforske strategiar for å løyse likningar, likningssystem og ulikskapar og argumentere for eigne tenkjemåtar

A.3.3 Theoretical Math (year 11)

Kompetansemål

Mål for opplæringa er at eleven skal kunne

- formulere og løyse problem ved hjelp av ulike problemløysingstrategiar og digitale verktøy
- lese og forstå matematiske bevis og utforske og utvikle bevis i relevante matematiske emne
- identifisere variable storleikar i ulike situasjonar, setje opp formlar og utforske desse ved hjelp av digitale verktøy
- utforske strategiar for å løyse likningar, likningssystem og ulikskapar og argumentere for eigne tenkjemåtar
- forklare forskjellen mellom ein identitet, ei likning, eit algebraisk uttrykk og ein funksjon
- utforske samanhengar mellom andregradslikningar og andregradsulikskapar, andregradsfunksjonar og kvadratsetningane og bruke det i problemløysing
- modellere situasjonar knytte til realfaglege tema, presentere og argumentere for resultata og argumentere for at modellen er gyldig
- lese, hente ut og vurdere matematikk i relevante tekstar knytte til realfaglege tema og presentere relevante berekningar og analysar av resultata
- utforske eigenskapane ved polynomfunksjonar, rasjonale funksjonar, eksponentialfunksjonar og potensfunksjonar
- bruke gjennomsnittleg og momentan vekstfart i konkrete døme og gjere greie for den deriverte som funksjon
- forklare polynomdivisjon og bruke det til å omskrive algebraiske uttrykk, drøfte funksjonar og løyse likningar og ulikskapar
- gjere greie for definisjonane av sinus, cosinus og tangens og bruke trigonometri til å berekne lengder, vinklar og areal i vilkårlege trekantar
- grunngi sinus-, cosinus- og arealsetninga
- bruke trigonometri til å analysere og løyse samansette teoretiske og praktiske problem med lengder, vinklar og areal

A.3.4 STEM Math (year 12-13)

Kompetansemål etter R1

Mål for opplæringen er at eleven skal kunne

- gjøre rede for definisjonen av potenser med rasjonale eksponenter og sammenhengen med eksponentialfunksjoner
- gjøre rede for definisjonen av logaritmer og utforske egenskaper ved logaritmer
- forklare de grunnleggende regnereglene for logaritmer og potenser med rasjonale eksponenter og bruke dem til å forenkle uttrykk
- utforske og bruke ulike strategier for å løse eksponentialligninger og logaritmeligninger
- modellere eksponentiell og logistisk vekst ved å bruke eksponentialfunksjoner og logaritmefunksjoner
- gjøre rede for begrepene grenseverdi og kontinuitet
- bruke ulike strategier for å utforske og bestemme grenseverdier til funksjoner og argumentere for egne løsninger
- diskutere om og argumentere for om en funksjon er kontinuerlig eller diskontinuerlig i et punkt i definisjonsområdet, og gi eksempler på funksjoner som ikke er kontinuerlige
- gjøre rede for definisjonen til den deriverte og bruke denne til å bestemme den deriverte, både geometrisk, algebraisk og med numeriske metoder
- gi eksempler på funksjoner som ikke er deriverbare og begrunne hvorfor de ikke er det
- argumentere for og bruke derivasjonsreglene for summer, produkter og kvotienter av funksjoner og for sammensatte funksjoner
- bruke første- og andrederiverte til å drøfte forløpet til funksjoner
- bruke derivasjon til å diskutere og løse optimaliseringsproblemer
- bruke den første- og andrederiverte i utforsking, problemløsing og modellering
- gjøre rede for hva omvendte funksjoner er, for hva som skal til for at en funksjon har en omvendt funksjon, og for sammenhengen mellom den deriverte til en funksjon og den deriverte til den omvendte funksjonen
- bruke digitale verktøy i beregninger og utforsking av egenskaper ved funksjoner
- planlegge, utføre og presentere et selvstendig arbeid knyttet til modellering og funksjoner i realfaglige temaer
- gjøre rede for begrepet vektor og utforske og diskutere regneregler for vektorer i planet, med og uten koordinater
- bruke vektorregning til å beregne lengder, vinkler og arealer i planet med ulike strategier
- bruke vektorer i argumentasjon og problemløsing
- gjøre rede for parameterframstillinger til linjer i planet og bruke parameterframstillinger til å løse geometriske problemer

Kompetansemål etter R2

Mål for opplæringen er at eleven skal kunne

- utforske regneregler for vektorer i rommet, både med og uten koordinater, og bruke addisjon, skalarprodukt av vektorer og vektorprodukt i problemløsing
- gjøre rede for begrepet normalvektor, og argumentere for hvordan en normalvektor kan brukes til å beskrive et plan i rommet ved en ligning
- regne ut og begrunne utregninger av avstander i rommet
- tolke og finne parametriseringer av kurver i rommet og forklare begrepene hastighetsvektor og akselerasjonsvektor
- utforske tallmønstre og finne rekursive og eksplisitte formler for følger og rekker, og presentere og argumentere for egne løsninger
- bruke programmering til å utforske rekursive sammenhenger og presentere egne framgangsmåter
- gjøre beregninger og vurdere valg knyttet til økonomi, og reflektere over konsekvenser ved kredittlån
- avdekke de bærende ideene i et matematisk bevis og lage og forklare bevis
- beskrive vinkelmålet radianer og utforske egenskaper ved trigonometriske funksjoner
- forklare og bruke grunnleggende trigonometriske identiteter
- utforske, forklare og bruke derivasjonsregler for rasjonale funksjoner, logaritme- og eksponentialfunksjoner og trigonometriske funksjoner, og bruke slike funksjoner og deres deriverte i modellering og problemløsing
- analysere data knyttet til realfaglige temaer og bruke trigonometriske funksjoner i modellering
- gjøre rede for definisjonen av det bestemte integralet av funksjoner med én variabel som grenseverdi for en sum, og gi en tolkning av hva denne grenseverdien kan bety i ulike situasjoner
- formulere algoritmer som beregner bestemte integraler numerisk og bruke digitale verktøy til å utføre algoritmene
- begrunne og bruke analysens fundamentalteorem
- bruke og forklare de grunnleggende integrasjonsmetodene substitusjon, delvis integrasjon og delbrøksoppspalting
- bruke integrasjon til å beregne areal og volum

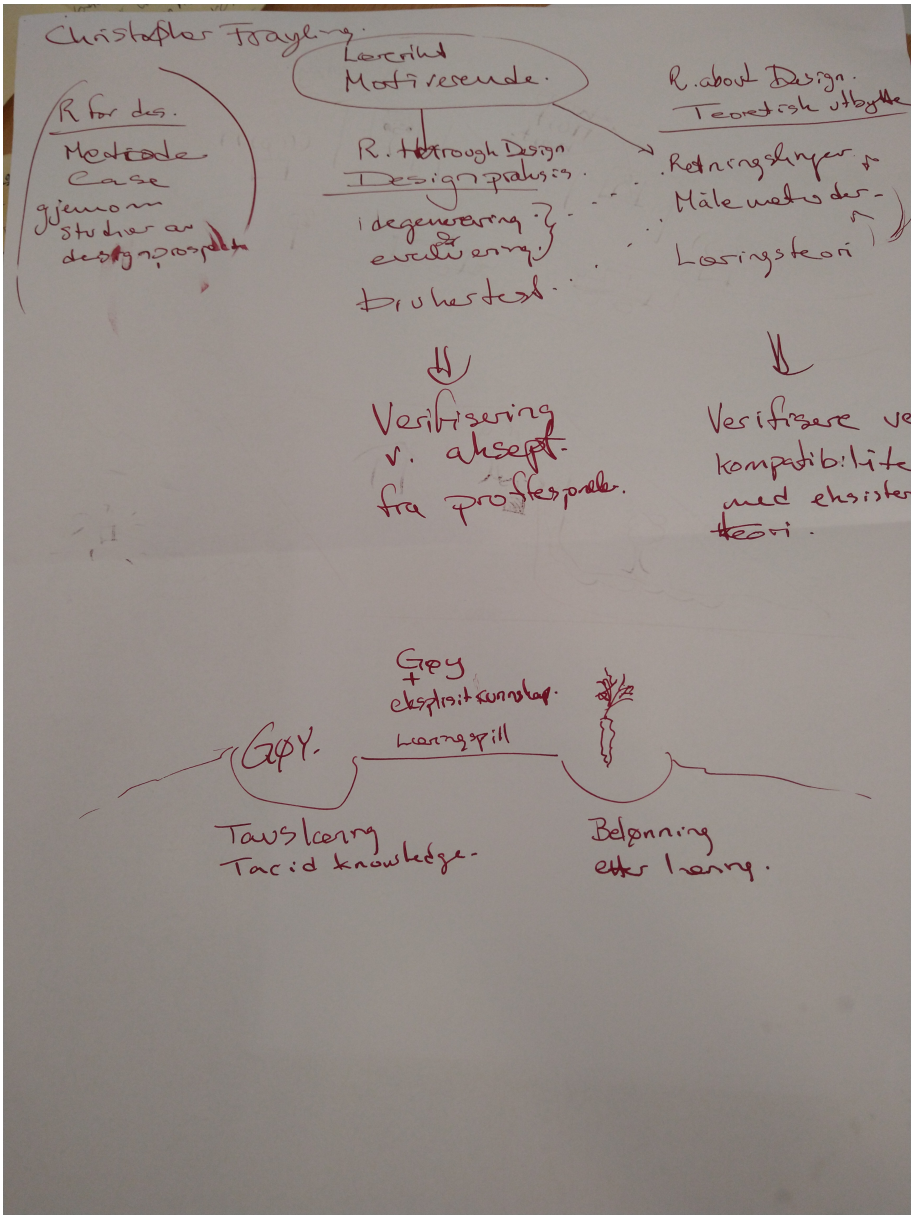
A.4 List of Game Ideas from Ideation Process

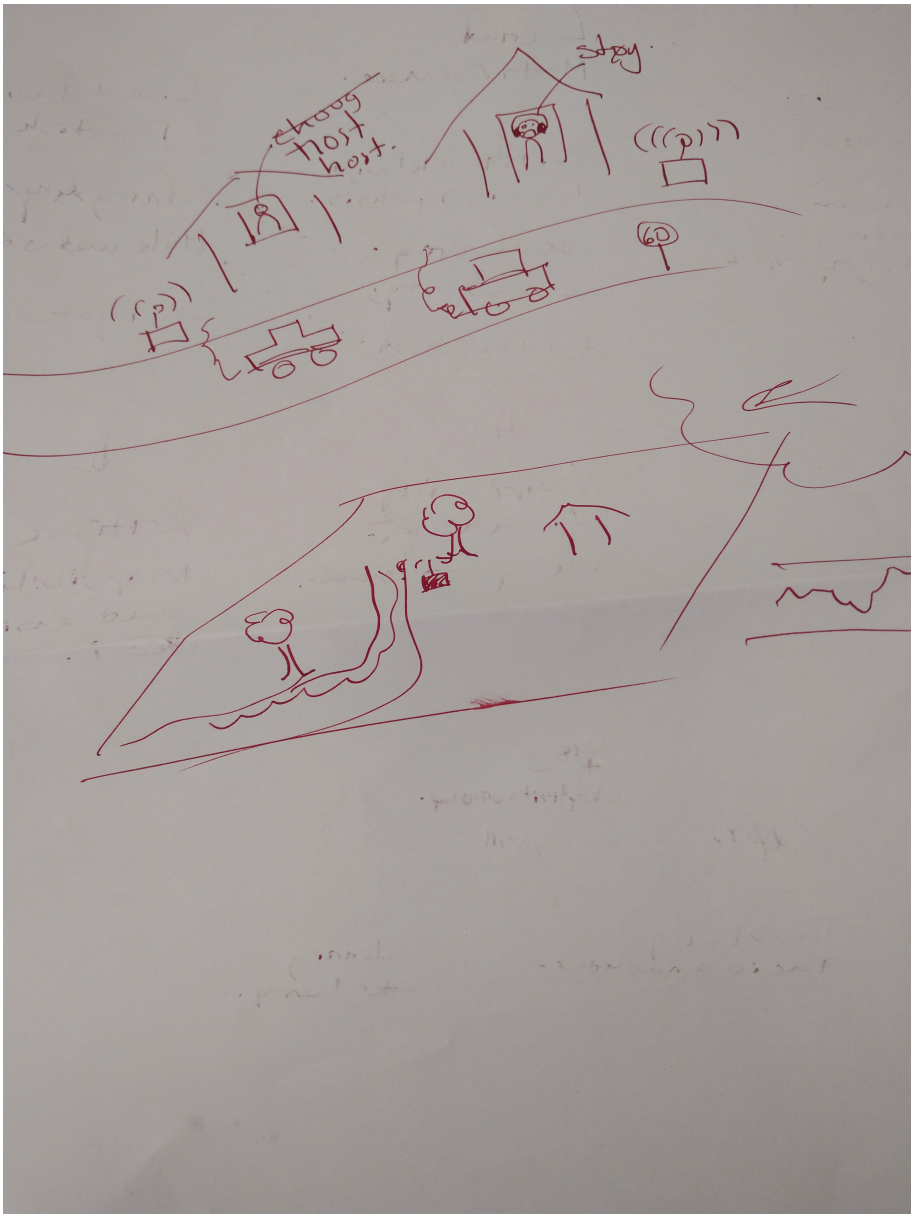
- Using real a world sensor to collect data
  - Collecting air quality data from local environment
  - Collaborating to understand how to use sensor
  - Real world sensor being the source of initial currency in game
  - Prompting the use of other sensor equipment (pcs, smartphones)
- Sensors collecting noise from environment
- Controlling the variables of a sensor environment, and gaining insight into using data
  - Controlling traffic to see effects on pollution
- Puzzles where the clues are found in the data - narrative driven
- Sensors collecting data from different areas

- Control engineering
  - Measuring levels of toxin in a lake or in the air
  - Detecting the rise and fall in levels through sensors
  - Creating an alarm system to warn when critical levels of toxin are reached
-

A.5 Expert Interview Notes

During the co-design session described in chapter 5, notes were made in cooperation between interviewer and expert. Excerpt from the notes are included as documentation. These may also be helpful for understanding the ideation and iteration during the session.


Christopher Frayling.
Laercrild
Motiverende.
R for des.
Metode
Case
gjennom
studier av
R. through Design
Design praksis.
i degenerering
evaluering
brukertest.
R. about Design.
Teoretisk utbygde
Retningslinjer
Måle metoder
Laringsteori
Verifisering
v. aksept
fra profesjonelle.
Verifisere ve
kompatibilite
med eksister
teori.
Gapy
+
eksplisit kunnskap.
Laringspill
Gapy.
Tausleering
Tacid knowledge.
Belønning
etter laering.


stay
stay
host
host

Lars Møster

NTNU
Norwegian University of
Science and Technology