Building Blocks for Gamification in the Digital School

Ole-Alexander Rostad Kjeserud and Sigrid Rein Trustrup

Department of Computer Science

Norwegian University of Science and Technology

Supervisor: Trond Aalberg

Preface

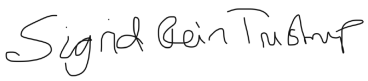
This master's thesis is part of a Computer Science degree at the Norwegian University of Science and Technology. The project was carried out over the span of two semesters, starting autumn 2018 and finishing spring 2019. The thesis was undertaken with supervision of associate professor Trond Aalberg.

In the beginning this project looked quite different from what it now is. The motivation behind this project lies in the fact that we have a strong interest in digital learning among children and teens. We ambitiously thought we could develop a single platform that could be a substitute for a large number of platforms and software in the Norwegian school system, e.g Itslearning, Kikora, Google Sites, Khan's Academy etc. With the goal to meet the need for simplicity, a learning platform and safe and fun learning in a digital environment. In other words; One platform to rule them all. We soon realized that we had to narrow our thesis down substantially. Therefore, this thesis explores the "fun learning in a digital environment" aspect. Further reading will reveal in greater detail what that entails.

Trondheim, 2018-06-01

Ole-Alexander R. Kjeserud

Trondheim, 2018-06-01



Sigrid R. Trustrup

Acknowledgment

We would like to thank our supervisor Trond Aalberg. First of all for having faith in us and our idea. Furthermore, for good advise and guidance throughout this project. It is only right to also give thanks to the enthusiastic middle school teachers who helped us with insights into usage of digital aids in a local secondary school. As well as all the other teachers who helped us broaden our perspective and contributed with their experience. Lastly, we have to thank our family and friends who have shown us great support this past year.

Summary and Conclusions

In an attempt to uncover ways to improve the quality of education through technology, this thesis has identified several gamification elements, pedagogical techniques and assignment formats that has potential. A literature review was conducted to shed light on how and why these elements work. Furthermore, state of the art digital learning systems from industry and academia have been evaluated to see if these elements have been used. If so, how have they been implemented, and how do they perform. Most digital learning systems found in research papers are tested on college students. It is therefore hard to tell if their findings will extrapolate to younger learners. A review of the digital learning system industry shows that most digital learning systems focuses on a small set of elements. There are still many elements in theory that have not yet found its way into practise. All digital learning systems found in the industry today relies heavily on the use of multiple choice, in terms of assignment formats, with some variation on specific task types.

Additionally, a set of functions to model adaptive learning, competence and spaced repetition have been developed for use in early iterations of a digital learning system. These models could be stepping stones on the road to gathering a solid amount of data that may be utilized by more efficient and complex algorithms. As a compilation of the information gathered throughout the thesis a prototype was created and usability tests were conducted. Finally we discuss potential benefits of more digital solutions in education, as opposed to the current school situation.

Sammendrag og Konklusjon

I et forsøk på å finne måter utdanning kan bli forbedret på ved hjelp av teknologi, har denne masteroppgaven identifisert flere spillifiseringselementer, pedagogiske teknikker og digitale oppgaveformater med potensiale. En litteraturundersøkelse ble utført for å synliggjøre hvordan og hvorfor disse elementene fungerer. Videre ble de nyeste læringssystemene fra akademia og læringsindustrien evaluert, for å se om disse elementene har blitt bruk. Dersom disse elementene har blitt brukt, hvordan var de implementert, og hvordan presterer de. De fleste læringssystemer funnet i forskningsartikler er testet på studenter i høyere utdanning. Det er derfor vanskelig å si om funnene gjort i disse artiklene kan overføres til yngre elever. En undersøkelse av læringssystemer fra læremiddelindustrien, viser at de fleste læringssystemene fokuserer på et lite sett av elementer. Flere av elementene funnet i teorien har enda ikke blitt tatt i bruk av digitale læringssystemer. Alle digitale læringssystemer bruker i stor grad flervalgsoppgaveformater i sine oppgaver, med unntak av noen spesialformater for spesifikke oppgavetyper.

I tillegg har det blitt utviklet et sett med funksjoner for å modellere adaptiv læring, kompetanse og oppgaverepetering til bruk i den første fasen av et læringssystem. Disse modellene kan bli brukt frem til nok data er samlet inn, og mer sofistikerte modeller kan utvikles. Som et sammendrag av informasjonen samlet i denne oppgaven har det blitt utviklet en prototype, som ble evaluert gjennom brukervennlighetstester. Til slutt diskuteres potensialet gode digitale løsninger kan ha i skolesystemet, sammenliknet med dagens skolesystem.

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Chapter 1

Introduction

1.1 Background and Motivation

The Norwegian government decided in 2006 that basic computer usage should be introduced in the upper secondary school curricula as a cross disciplinary skill. Since then the availability of digital tools like laptops and tablets increased throughout the school system as a whole. Even though the Norwegian school system is regarded as one of the leading parties in the digitization race, there are lot to be desired on the software side. General purpose software like text editors, spreadsheets and web browsers are the most commonly used applications in the Norwegian classrooms today. The applications made for education are few. It is up to the individual teachers to find, learn and utilize such applications in their classes[3]. Leaving the digital education quite uneven and variable for the learners. The potential in educational software is not only limited to interactive assignments. Data aggregation and advances in machine learning enables the possibility of dynamic learning progression and automated grading, giving learners instant feedback and saving time for the educators, as well as creating insight for researchers and legislators.

As entertainment rapidly improves in availability and quality traditional educational methods become less effective and motivating. It is apparent that education is in need of revitalization if it is to compete for learners time and attention.
Gamification has become immensely popular the last two decades. Usage of gamification promises to increase motivation and give insight into real world applications of the material. We believe that the digitization in the school still has a long way to go, and with it much untapped potential for developing great learning tools for everyone. Through this master's thesis we hope to contribute to the knowledge pool of gamified education, and raise awareness in the field.

1.2 Project Goal

The overall intention of this master thesis is to look at how digitalization and gamification can contribute to improved learning and motivation among learners in the Norwegian public school system (year 1 - 13). Specifically, these research questions will be attempted answered in this thesis:

- **What gamification elements exist in current literature and industry?(RQ1)**
- **Which of these gamification elements are viable candidates for use in the Norwegian public school system? (RQ2)**
- **What digital assignment formats are used today in gamified learning systems?(RQ3)**
- **What are the possible effects of utilizing gamification elements and digitized assignments as pedagogical tools in the Norwegian public school system?(RQ4)**

To answer **RQ1** a survey of current literature and commercial learning systems is conducted. The results of this survey will be a mapping of existing gamification elements, how they work and how they contribute to learning. This mapping is the foundation of **RQ2**, which is answered through interviews, questionnaires and how practical the respective gamification elements are in a public school context. **RQ3** is a survey of current commercial assignment formats. These formats will be the subject of gamification in a digitalized education system. **RQ2** & **RQ3** is combined in a conceptualization of a educational system. **RQ4** is answered in a more philosophical manner. Hurdles, advantages and future possibilities predicated on theory and experiences aggregated throughout the project will be discussed.

1.3 The Significance of the Thesis

There is an ever-growing need for better and more efficient schooling as our knowledge continually expands. To keep up with the times and technological stride, the Norwegian government funds the development of digital learning material for use in the public school system, from year 1 to year 13. The result is several digital learning systems with different approaches and various functionality and degrees of gamification. This thesis can benefit developers of educational software by pinpointing weaknesses and shortcomings in current educational software. It can also benefit teachers and school administrators in what to look for, when evaluating software to use in their pedagogical practises. The main contributions are:

- The identification of gamification elements for educational uses grounded in motivational theory and teachers professional opinions through interviews and a questionnaire.
- A set of models to be used in adaptive learning and spaced repetition for early stages of data collection. Where the data can be used in more efficient algorithm at a later time.
- The thesis proposes a set of assignment formats to be used individually and in group work.

- Four next generation learning platforms were evaluated.
- A clickable prototype were developed incorporating gamification elements and pedagogical tools found suitable. Three usability tests were conducted on the clickable prototype, which demonstrates viable gamification elements for use in the Norwegian public school system.
- Advantages of specialized software in education are discussed.

1.4 Structure of the Report

The rest of the report is structured as follows; Chapter 2 establishes the theoretical background on gamification, motivation and pedagogy for the work in this thesis. Further on presenting insights collected from relevant professionals in chapter 3. Chapter 4 introduces work done in both academia and industry regarding gamification in an educational context. Chapter 5 and 6 covers the development and evaluation of the prototype. The accumulation of all previous chapters will come together in a discussion in chapter 7, and conclude the thesis in chapter 8. This includes a reflection of the process and recommendations for further work.

Chapter 2

Theory

This chapter will introduce the theoretical foundation for this thesis. Presenting concepts and theories surrounding gamification, motivation and pedagogy, and the relationships between them.

2.1 Introducing the Concept of Gamification

When entering this particular area of study the lines tend to become blurred when it comes to definitions and classifications. The abundance of related concepts are confusing, and more often than not overlapping. To mention a few: Serious Games, Game Thinking, Pervasive Games and Playful Design. This will be an attempt to navigate the topic of gamification without too much digression. Starting out by presenting Deterding et.al.'s proposed definition of gamification, it reads as follows:

> "Gamification is the use of game design elements in non-game contexts." [4]

What can be gathered from this definition is that gamification is about transferring game-like artifacts and experiences into new situations. Many who seek to gamify a system adopts the well known artifacts; points, badges(also known as achievements) and leaderboards, which is a staple in many games these days. A naive implementation of gamification elements does not guarantee a successful system. Such an approach limits gamification, and kills the tremendous potential it has to teach and motivate. Andrzej Marczewski, author of gamified.uk, attempts to clarify the difference between gamification, serious games, playful design and games with the figure below, Figure 2.1 [1].

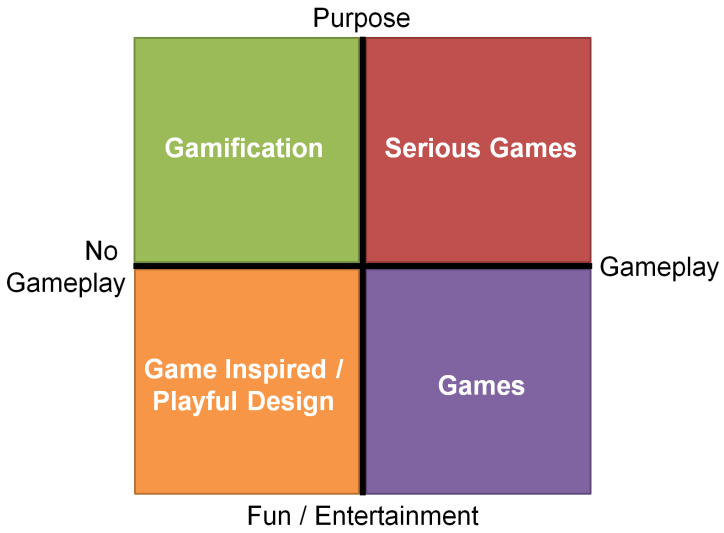


Figure 2.1: Game thinking quadrant [1]

Even though Figure 2.1 does not directly define each concept, it does however, highlight differences and similarities such that it may become clearer what they are, and are not. Gamification and Serious Games share the underlying intention of having purpose, nevertheless separated by the presence of, or lack of, gameplay. With that said, Marczewski also stresses that

> "these approaches flow between each other and can be mixed and matched."

This goes to show the fluidity and adaptability of gamification, and gives a hint at the scale of which gamification may be applied.

Nick Pelling is regarded as the father of the term gamification. He comes with 20 years of experience in the game industry. In the early 2000s he began a new path with a Masters of Business Administration. In his own words, he saw a revolution begin, and there was no word to describe what was happening [5]. The world was taken by gamification. New devices came and changed our relationship/perception with/of these devices/technology. At the Gamification World Congress 2014 Nick Pelling describes it like the game industry washed over the world with a new mindset [5]. Bringing immersive interface design and digital content platforms (e.g. App Store and Steam) outside the game sphere was, according to Pelling, the dawn of gamification.

Today, and for the last decade or so, the term gamification has been a buzz word and everyone has wanted a piece of the pie. The versatility and adaptability of gamification has allowed it to flourish in a wide range of areas; from health care to business, to education and to in-house training and more. Two examples which demonstrate its flexibility are: productivity app *Forest App* [6] where one plants a digital seed and let it grow by not using the phone, and the TheFunTheory initiative by Volkwagen, who made a speed camera lottery to help people keep the speed limit [7]. In these examples several common gamification elements have been utilized to achieve the intended result: (Epic) meaning/purpose, achievements, customization and social pressure. These gamification elements and more will be thoroughly presented in due course.

In narrowing it down to gamification in an educational context there is need to expand, yet specify Deterding et.al.'s definition of gamification. The "leading research and advisory [IT] company" [8] Gartner defines gamification like this:

> "[*Gamification is*] the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals."[9]

A significant difference between the two definitions is the inclusion of peoples psychology in the latter. For this reason, Gartners definition is immediately more appealing in an educational context, even though it was formulated for business purposes. In education, motivating learners to learn is key, and therefore gamification is often seen as a promising solution in the learning process. Buckley and Doyle suggests:

> "The interest in gamification arises from the idea that it influences behaviour" [10].

This sentiment substantiate why gamification is such an attractive concept in numerous areas, including education, where the primary purpose is for learners to acquire knowledge and skills and desirable behaviour.
Gamification uses a multitude of techniques to achieve the intended effect; learning, changing or regulating behaviour and motivate. It takes inspiration from the field of psychology as much as from game design. Well executed gamification takes advantage of how people are motivated and how they learn. Gamified learning systems use theories from pedagogy to substantiate the learning effect. It is therefore not a bold claim to insinuate that gamification is a cross-disciplinary concept with a large variety in subject matter.

2.2 Motivation - Understanding Gamification

As professed previously, behind the scenes gamification takes advantage of the human psychology. This is true specifically when it comes to human motivation. The ultimate goal of gamification is to increase motivation in people. Motivate people to do something they wouldn't do naturally. Motivation is the propeller behind human behaviour [11], and there are an abundance of theories on the subject. The most relevant theory regarding gamification is Self-Determination theory with the concepts of competence, autonomy and relatedness. Self-Determination theory along with the concepts of extrinsic and intrinsic motivation is the bulk of this chapter.

2.2.1 Extrinsic and intrinsic motivation

Many theories on motivation defines extrinsic and intrinsic motivation. Intrinsic motivation is the essence of Self-Determination theory. It is what drives us to exploration, to novelty and challenge. Intrinsically motivated activities are in themselves rewarding, and does not need external reward to be engaging. Autonomy and a feeling of competence are factors that are known to enhance intrinsic motivation. Other factors that may contribute to intrinsic motivation, although controversial are extrinsic rewards and fulfillment of psychological needs. Effects known to diminish intrinsic motivation are lack of autonomy i.e. a strictly controlled tasks, with little room for exploration,

deadlines, punishment, imposed goals and pressured evaluations [12].Extrinsic motivation may be outer influences like rewards in the form of a pay check or allowance or praise for a job well done. It may also be the cause of internal mechanisms like feelings of guilt and shame.

> "Positive reinforcement strengthens a behavior by providing a consequence an individual finds rewarding [13]."

This is the fundamentals in Incentive Theory by Skinner. Thus, in Skinner's Incentive Theory, behaviour is dictated by what individual people find rewarding. Which means the same reward doesn't necessarily work on everyone. Intrinsic and extrinsic motivation theories takes this into account too. Dividing intrinsic and extrinsic motivation in three types each [14]. *Intrinsic motivation to know*, which is has a strong association with education, is being motivated by the experience of acquiring knowledge. On the other hand, *intrinsic motivation towards accomplishment* is taking pleasure and satisfaction in finishing a challenging activity. Last intrinsic motivational type is *intrinsic motivation to experience stimulation*. Meaning an activity is pursued in an attempt to be stimulated. For instance intellectually, for sensory or aesthetic pleasure [14]. An example being: Some seek out roller coasters. It gives a sense of excitement and terror, and people do it for fun.

Rather than separate sub-entities like intrinsic motivational types, extrinsic motivational types are consider to be on a scale from low level of autonomy to high level of autonomy. *External regulation* have the lowest level of autonomy, and engaging in an activity is done to please or avoid penalty from an external source. Further, is *introjected regulation* which is defined by motivation to enhance oneself on behalf of external factors. The most autonomous extrinsic motivational type is *identified regulation*. This occurs when an individual chooses certain behaviour to be part of their identity. E.g. A learner considers himself a good student so the motivation for doing his homework is linked with his perception of being a good student.

2.2.2 Self-determination theory

Self-determination theory(SDT) was first developed by Edward L. Deci and Richard M. Ryan.

> "[SDT] is made up of several mini-theories which fuse together to offer a comprehensive understanding of human motivation and functioning." [15]

The reason for SDTs introduction is that gamification is closely tied to the core concepts of SDT. There are six mini-theories. The fourth mini-theory called *Basic Psychological Needs Theory* is the common thread throughout. It presents three psychological needs to be satisfied for humans to "flourish and grow" [15]: autonomy, competence and relatedness.

Autonomy is about the feeling of freedom, of a willingness to do something because you want to do it. To have control of your own life. Feeling competent, whether it is in a specific activity or more generally in life, is important

to be a healthy human. Constant failure will lead to negative effects on the psychological health, and the overall well-being will drop [16]. Relatedness is about having meaningful connections with other people [15]. Feeling liked and being part of a community, tiny or large, is all important to produce satisfied humans. Essentially, the fourth mini-theory says that when the three psychological needs are fulfilled, positive feelings emerges and people are satisfied with themselves. Negative feelings appear when satisfaction of the three needs are low.

> "When one, two or all psychological needs are met, people evaluate their behavior to be self-determined. This state is also called intrinsic motivation [17]."

What is worth mentioning is that for each individual satisfaction and frustration levels are measured on a scale, and the level of satisfaction/frustration in relation to well-being is individual. Putting SDT into a learning context means that teachers must know their learners individual satisfaction/frustration levels to facilitate for their optimal level of motivation to learn.

Some of the gamification elements highlights the users progress through progress tracking, achievements and others described in detail in section 2.3. Highlighting the users progress makes the user more aware of their progress and accomplishments, and in turn fortifies the users feeling of mastery. Parallels can also be drawn from autonomy and relatedness to other gamification elements. According to basic psychological needs theory, fulfilling these needs leads to personal satisfaction, while the lack of fulfillment leads to withdrawal, apathy and even hostility. As such, using gamification elements in an educational context must be carefully deliberated and executed.

2.2.3 Motivation and Learning

Motivation is an important part of the learning process. Motivation is first of all necessary to partake in the learning activity. Intrinsic motivation has also been proven to increase learning efficiency. Kang et.al. [18] uses functional magnetic resonance imaging to see how curiosity affects brain activity, and test how learning during curiosity affects memory retention. They found that long and short term recall was better among curious subjects. Memory retention is not only better for the subject responsible for motivation, but other observed information during the heightened state of curiosity. Similar studies have been conducted on extrinsic motivation.

2.3 Gamification Elements

A study by Buckley and Doyle identified four basic gamification elements as relevant and eligible in an educational context. The elements being: Objectives, rewards, rapid feedback cycle and competition [10].
This section will introduce a large variety of gamification elements that are found in non-game contexts. The underlying purpose of each gamification element will be presented. What will become clearer is that a gamification element not necessarily is a viewable feature such as a digital badge as a reward, but also includes more intangible concepts, such as dynamic difficulty and exploration. The purpose of the elements are either to motivate the learner, or to increase the learning efficiency, preferably both.

Adaptive Learning

Adaptive learning has the purpose of guiding the individual learner through the learning process with the pedagogical goal of optimizing learning efficiency. Though adaptive learning isn't a gamification mechanism in itself, it has a clear parallel to dynamic difficulty in games. In games dynamic difficulty has the task of keeping the player engaged by keeping the game difficult in a balance between easy and hard. If the game is too easy, the player becomes bored and loses interest. In the opposite case that the game becomes too hard, the player will get discouraged [19]. A good difficulty balance gives the player a sense of achievement and maintains the players motivation. There are a few reasons to why this is an important mechanism in learning. Motivation not only increases learning efficiency [20], but also drives self sufficient learning. It can ensures that fundamental concepts are adequately understood before moving on new material dependant on these fundamentals. Learning is not a linear process, some may learn faster if the curriculum is sequenced differently, or with a different repetition frequency.

Points, Badges and Leaderboards

Points, badges and leaderboards, also known as PBL, are well known gamification mechanics. PBL is quite straightforward: Points are awarded a player for what is considered right behaviour, badges or achievements are awarded for players achievements and leaderboards are an overview of the highest scores/best players in a digital society/game. These mechanics are widely used in various situations and applications. Yu-kai Chou, who is considered a world authority on gamification, has called out PBL as the "shell of [a] game experience" [21]. He argues that the frequent and shallow usage of PBL has damaged the reputation of gamification and its potential to have an impact. The reason for using points, badges and leaderboards is to increase the players motivation to strive for better results. It is rewards that may satisfy the extrinsic motivation. Also, points and badges are methods of giving feedback on the players performance and/or progress. In addition, badges can signalize a milestones. Adding leaderboards to the experience extends it to become a comparison of other players, and so an element of competition is achieved. The fact that these three gamification mechanics are easy to implement may be a contributing factor for the widespread usage today. PBL is generally considered effective motivators, but it will however not make an activity in itself fun (intrinsically motivating). None the less, it is suggested that PBL can increase student motivation to do more learning activities and invest more time in learning if present [22].

Meaning/Purpose

For some, doing their assignments for the sake of doing their assignments, or for a quick reward, is not a satisfactory reason. In games, a higher purpose may be how your sub-tasks affect a larger game world, or to understand the game characters motivation for doing the tasks. In a learning context purpose may be built by informing the learner on what they will learn by doing the assignment, and what applications it may be used for and why it is important to learn.

Customization

Customization is about allowing the player to have freedom to choose and affect their experience. Whether it is choosing hair and eye color of their own avatar, or the sequence of tasks to be done. Customization can be tied to the Self-determination theory that introduces the basic psychological needs of autonomy, relatedness and competence. The need for autonomy is the most relevant when considering the gamification element customization. The need satisfaction for autonomy can be fulfilled by supporting freedom to customize an experience to a degree. It must be taken into account that need satisfaction and frustration is individual. Games often present an illusion of freedom or abundance of options, when in reality there are only two options that affect the game. In a learning situation autonomy can be achieved by learners having several homework options. E.g. learners choosing whichever task they find most interesting, or allowing the option to choose a slightly higher difficulty level.

Flow

Flow is a state of mind. Csikszentmihalyi et.al. defines flow in the following way:

> "[..] a subjective state that people report when they are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself" [23]

Flow can be achieved in various activities, but it is essentially hard to bring about. Games are known to promote flow in players. Those who have been successful in achieving flow among their players are Civilization V [24] and Freecell Solitaire [25]. Flow is closely related to motivation, and according to Csikszentmihalyi one can develop intrinsic motivation in almost any activity if flow is obtained. Therefore, it would be prudent to facilitate for flow among learners. To achieve flow Csikszentmihalyi suggests a few ground rules [23]. Those rules include having tasks with clear goals and immediate feedback, and a balanced challenge to skill ratio. The tasks should also invoke "a sense of control over [the] actions" made and the end results. And finally, the tasks should require a cognitive effort to promote concentration.

Quests

Quests are actions or tasks which usually result in an award. This can be a single task or a composition of tasks. It is common to track progress throughout the course of the quest. In school, a quest may be to do a set of assignments within a given time frame. In turn, doing school work sounds epic. Such quests can be cooperative and may be part of a larger event in the classroom, leading up to a great reward for the class collectively.

Exploration

To break away from the paved path gives the player a sense of freedom. The players reason for exploration may be the result of the current task being too hard or too easy, a need for novelty, or just boredom. Autonomy is an essential factor in intrinsic motivation, and a lack of autonomy can be detrimental to the players motivation.

Loss aversion

The risk of losing points or progress can be a motivation factor for recurring usage. In an educational setting this can be to avoid having to do repetition exercises, losing some type of skill measure, or missing out on a scheduled reward.

Theme

A recurring theme can bind the gamified object together. It will give the player a sense of familiarity throughout the game, or across multiple games.

Progress Tracking and feedback

Progress tracking and feedback can be useful in multiple ways. It can motivate the player by assuring that progress is being made due to their interaction. Feedback can mark milestones, reinforcing a feeling of accomplishment. Progress tracking can be useful in showing progress towards long term goals, when the contributing parts to that goal can seem insignificant, like doing assignments to improve your semester grade. A character in a role playing game may have a metric that tells the player how much the character has progressed in magic abilities. Most learners already have grades telling them how well they are doing in their subjects. Moving the grades into the game will give the learners a continuous indication of their skill, and something they can influence by interacting with the gamification, and not something they won't be able to influence once they get the grade. A progress measure is also a source of reinforcement. If the performance measure progresses it means they have done something right.

Teams

Working with others towards a common goal can both be motivating and fun. Teammates can provide a helping hand in times of need. Helping a team member can give a feeling of mastery. Teamwork also has pedagogical advantages. If for example a team member does not understand a task or concept, simply repeating the teachers instructions is not helpful. To help the team member understand the learner has to reinterpret the task from the perspective of the team member. This increases retention and gives the learner a broader understanding of the material. Being in a team means that the individual learner is no longer only responsible toward itself, but is relied upon by multiple peers.

Easter eggs

Easter eggs are hidden things inside a game. It can be anything from in-game rewards to something not game related the developer thought would be funny to hide in the game. Finding Easter eggs can be rewarding in itself, even if it has no impact or meaning in the game. Although there are not any research on how Easter eggs contribute to concentration, it is not unreasonable to think that a learner on a constant lookout for Easter eggs is more concentrated. Higher levels of concentration improves memory retention.

Competition

Competition is when two or more entities compete against each other as individuals or as part of teams. As a game mechanic, competition can be used to make the players a part of the game content. Making the players a part of the content gives the game a great amount of variability and in turn increases replayability. Competition can turn a simple set of rules into vast timeless games like chess and poker. Competition is a simple yet effective source of novelty. Through competition one gets to compare ones abilities to that of its peers. This is an arena for both relatedness and competence, which is two of the basic needs in self-determination theory. However, some research indicate that not all types of competition promotes learning [26].

Sound

Sound effects and music are common features in games, and is a powerful tool. Often used to set the mood, or guide the players actions. There is an expectation that actions have corresponding sound effects. For example, in RPG games when the player's character runs the sound of foot steps are heard. In that way, keeping the illusion of the game world. No sound in a game may be dull or disconcerting. Music can be recurring for a type of situation or a person, and so give a hint to the player of what is to happen next. In other words sound effects and music are used to give the player information. In a learning context sound effects or musical tunes may be used as additional reward for the learners accomplishments. Sound is partially attributed to the addictive nature of slot machine [27]. See section 2.3.

Knowledge Sharing

Knowledge sharing among learners may be a desirable pedagogical tool, as to mediate learning material to co-learners requires good comprehension of the learning material. Knowledge sharing may therefore appear as a subject of gamification (which it can be e.g. Stack Exchange), rather than a gamification element in itself. Viewed from a STD perspective, helping others may provide a feeling of competence, enforcing intrinsic motivation. For knowledge sharing to be possible, the learners need to be able to communicate. This does not necessarily have to be within the gamified object, but in a third part application or in the physical world.

Camouflaging Loss

Used in the casino industry to make players feel like they have lost less than they actually have. This effect is achieved by emphasizing wins and down playing losses. In addition to this small payouts are shuffled in between losses. In some cases players may even think that they are winning, when they have in fact lost money [27]. This effect is ideal in education. It can help learners who easily get discouraged by failing. Failing is after all part of the learning progress.

Near Miss

When there are marginal differences between failure and success, the feeling of the result is enhanced. If a player loses by only a small amount, the player is likely to try again, often attributing the loss to a bad luck. This increases the chance that the player will try again. A marginal victory is perceived as more exiting [27].

Reward

A reward does not have to be some thing that is given to the player, like points or achievements. It can be something the player has positive associations to, like fireworks or a smiling face. Aside from monetary payout, slot machines uses audio visual effects to reward the player. Audio visual stimuli can help enhance the overall game experience. It can also help create the illusion of better payout than is actually given. For example, online slot machines uses sound clips of coins hitting a metal tray, and animation of coins falling over the display. The actual payout is substantially less than what the sound and animation indicates. Randomness is used to enhance the effects of rewards. The behavioral response to random reward is fast. This behavior is also lasts longer when time between rewards increases, or stop altogether. Random reward schedules are proven to better than continuous- and fixed reward schedules in rats [28].

2.4 Facilitating Better Pedagogical Practice

Motivation through gamification is not the only way specialized software can contribute to education. Technology can help bridge the gap between practical and optimal pedagogical approaches. It was discovered in the preliminary interview, in section 3.1, that one of the teachers had used Khan Academy in his class to practice *flipped classroom*. This chapter identifies some pedagogical techniques technology can make more practical. It also identifies a few pedagogical techniques known to be poor, but are used because of practicality. It is not a comprehensive list, but rather a curated selection of pedagogical techniques applicable to digitalization.

2.4.1 Scaffolding

Scaffolding is in education a metaphorical construct an teacher builds around a learner. The purpose of this scaffolding is to accelerate the learning, or to enable the learner to accomplish goals it would not be able to on its own. In the case where the teacher makes changes with respect to learner interactions, is said to be *Adaptive Scaffolding* (AD), e.g. lowers the difficulty of a task if the learner is struggling. *Fixed scaffolding* (FS) is when the scaffolding does not change in the course of the learning. For example a teacher casting a wide net to cover all students in a class, or simply a list of concepts to be studied in sequence, like the table of contents in a text book. *No scaffolding* (NS) is when the learner is in charge of its own learning process [29]. Azevedo et.al. studies [29, 30] tests how the different scaffolding affects learners performance. The learners are tasked with learning about the human circulatory system. Pre- and post tests shows that learners are able to learn a more complex representation of the circulatory system with AD. NS is shown to be better than FS. A reason for this is that AD helps regulate the learners

learning in collaboration with the learners own learning regulation. The FS on the other hand may have obstructed the learners self regulation.

2.4.2 Active & Cooperative Learning

As opposed to passive learning, e.g. observing a lecture, active learning is when the learner actively participate in its learning. A meta analysis conducted by Freeman et al. [31] found that courses that used at least some active learning activities as part of classes, instead of only lectures, had higher grade averages. Learner in the active learner classes also were 66% less likely to fail the course, than the learners in the lecture only courses. The study also notes that active learning is effective in all course sizes, but appears to be most effective in smaller courses (less than 50 learners). One type of active learning is *Cooperative Learning*. Simply put, cooperative learning is when learners work in groups. However, in order for cooperative learning to be effective the cooperative activity needs to be properly implemented. How to properly implement a cooperative strategy depends on the context [32]. How many learners are going to work together? Is it just a couple, a handful learners, or maybe cooperation between groups? What is the groups objective? Is it a complex open ended task, or pair quizzing? What is the purpose of the activity? Only learning the course material, learning how to communicate the material, learning cooperative problem solving, or something in between? A few of these strategies are [33]:

- **Reciprocal Learning**, is when two learners form a team to coach each other. This strategy is used for gaining mastery of previously learned material. It also teaches the learners how to give constructive feedback, and provide adaptive scaffolding to others.
- **Decision Making**, is when the learners make decisions based on a combination of information and personal opinion. This strategy teaches to extract information about a topic to make informed decisions, using personal beliefs to make a decision on partial and ambiguous information, find alternative decisions, and reflect on the decisions made.
- **Jigsaw**, is an inter-team strategy, where each member in a team gets responsibility for a sub-task of the groups task. Members from each team with the same sub-task then form expert groups where they research their sub-task, before going back to their original groups to teach what they have learned to their group, and to solve the overall task. The jigsaw strategy teaches collaboration, task organization and group organization, and knowledge mediation.

Sharan [32] postulates that the contributing reason for why cooperative learning does not succeed is: The learners cooperative skills are not sufficiently developed for the cooperative strategy used. The objective of the cooperative task is not sufficiently defined. The task is not structured enough, or is too structured, relative to the group and task. The structure does not offer sufficient accountability and responsibility for the individual learner. The teacher only knows one or two cooperative strategies. The strategies the teacher do know may not be suited for the task, group or learning objective.

2.4.3 Flipped classroom

> "We define the flipped classroom as an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom [34]."

Flipped classroom is in the simplest sense a reversal of school activities. The passive learning previously conducted in the classroom, is now done at home. Practice previously performed at home, is now done in the classroom. The flipped classroom concept has emerged in the wake of the digital age. In the days of old lectures was thought to be the most efficient way to convey course information to the learners. With existing technology, teachers no longer have to hold the same lecture year after year. Now teachers can record their lectures and make them available for learners to view on their own time, and as many times as they want. It is also possible for multiple teachers and multimedia production professionals to collaborate to create high quality informational videos. When the learners watch these instructional videos alone, it frees up the time previously used for lectures, to other activities. It is postulated that this time is better spent on *Active Learning* strategies like Problem-Based or Cooperative learning. These activities will work as repetition for the content in the instructional videos, but also teach the learners how to express, utilize and communicate the information, along with general social and problem solving skills.

2.4.4 High Stakes Testing

High stakes testing is in context of learning a test of great consequence, where the result of the test may determine if, the learner will have to retake the class, if the learner will get accepted into it's preferred academic program, or get the desired job. These types of tests are widely used in higher education, and have in recent years become widespread in U.S and British public schools [35]. One reason high stakes testing is so widely used, is that it makes it easier to statistically measure quality of education over time, and compare educational quality between schools, in geographical and socioeconomic areas. While high stakes testing may be an asset in governance, it is highly controversial among educators, and education researchers [35].

The result of a high stake test may not completely be in the learners control. In most cases a test can't exhaustively represent the learning material, as it cannot be contained within the time constraints of the test. This means that there is some probability that the test does not cover areas where the learner excels. Another possibility is that a question in a test requires good comprehension of a concept to complete. Though the learner has an OK understanding of the concept, it may not be sufficient to correctly answer the question. In the eyes of the test, the learner has no knowledge of the concept at all [36]. Teachers may change their teaching style to optimize the test scores. This may include cutting parts of the curriculum that is not covered in the tests, and being more controlling in their pedagogical practices [37]. This teacher reaction to high stakes testing has shown to inflate the test scores, and reduce learners ability to generalize the material taught [38].

2.4.5 Spaced Repetition

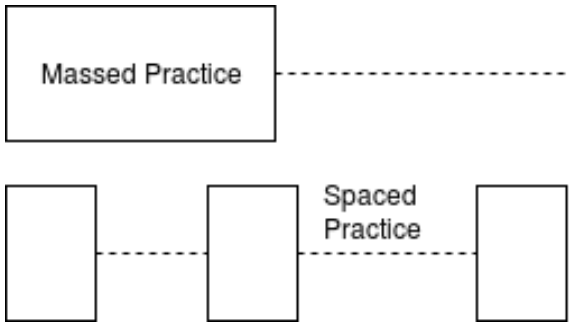


Figure 2.2: Example of spaced practice as opposed to massed practice.

Spaced repetition or distributed practice is the act of distributing a learning task across time, as opposed to doing all the learning at once (massed practice). Given the same time budget, cognitive studies suggest that long term retention is increased when using spaced repetition. There are several theories to why spaced repetition increases learning efficiency. Massed practice reduces the need for retrieval from long term memory, as most of the needed information is fresh in memory. This reduces the cognitive workload and in turn learning. Doing the same type of task over and over may reduce attention as a result of boredom, reducing learning efficiency [39]. Spaced practice may present different environments for the learning while the learning material stays the same, helping the brain separate the learning material from surrounding noise. It is uncertain how long the spaces between the repetitions should be, and if the optimal spacing depends on the learning material. An extended repetition schedule (the delay between repetitions is increased for every repetition) has shown promise in memory competition. Rohrer et al. [40] compares massed practice and distributed practice, trained on an equal amount of practice problems. The time between the two spaced practice sessions was one week. Results show that massed repetition is slightly better when tested after one week between last practise session (the only practice session for massed practice). When the period between last practice and test was increased to four weeks, test scores for massed repetition fell significantly, while the spaced group only fell slightly 2.3. Rohrer et al. continues to test the effects of overlearning. Overlearning is a stagnation in learning efficiency. Two massed learning schemes are compared. One group is given nine practice problems, and the other group three. Like the previous experiment both schemes are tested with one and four weeks between practice and testing. The results show that although nine practice problems was better than three in both cases, the difference was minuscule. It does not appear that an increase in assignments does not increase retention for massed practice.

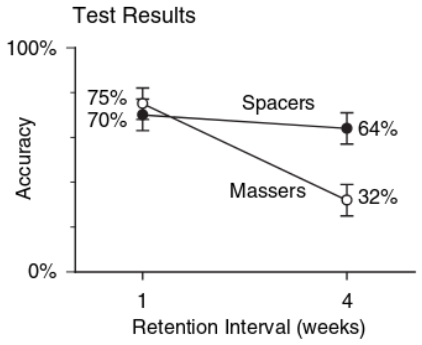


Figure 2.3: Test results of the four groups spaced repetition after one and four weeks, and massed repetition after one and four weeks

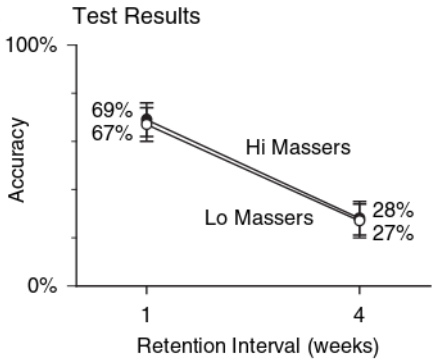


Figure 2.4: Test results of the four groups of three and nine massed repetition problems, one and four weeks after practice

Chapter 3

A Survey of Teachers and Experts

To increase the likelihood of making a strong contribution to the field a note from Human-Centred Design has been taken. Its key principle is to involve the humans that will be affected by the end-product in the development process. This chapter presents the insights gathered from teachers working in the Norwegian public school, and other relevant professionals. Two semi-structured interviews were undertaken and one survey was conducted. They will be presented in chronological order. Even though, teachers are not the primary users of a gamified learning system, they hold an important role for such systems to be approved and utilized.

3.1 Preliminary Teacher Interview

This was a preliminary interview conducted to get insight into digital tools in the school system from a teachers point of view. The two interview subjects were this schools' most experienced computer users, and were regarded as a resource for other teachers in matters of digital tools. One of the teachers had taken extra credits in computer science, and teaches programming in 8th and 9th grade. This school is considered to be progressive when it comes to IT in education, due to the municipality of Trondheim digitization strategies. This interview is only meant as an overview of what and how digital tools are used. This interview is not meant to be representative of the entire Norwegian school system.

3.1.1 Technologies used

Google Sites was used by both teachers as an information channel in their classes. The sites contained class schedules, homework assignments, and links to ebooks used in their courses.
Khan Academy and **Campus Increment**, have been used by one of the interviewees in math class. **Quizlet** and **Kahoot** for quizzing, though Kahoot is used more for collective fun. Quizlet is used for individual quizzing and individual drilling.

3.1.2 The Digital Classroom Today

The learners of both teachers use PCs or tablets in most of, if not all lectures. Mostly the learners use writing tools (Google Docs) and digital text books. Previously the digital books were only pdfs of scanned books. Recently they have started using *Unibok*, an online book reading tool and text book repository, tailored for school usage. All courses in this school is planned around a digital strategy developed by the teachers at this school. The strategy contains a "base", a set of technologies, and guidelines for how to apply them. This base is now composed of Google Sites and Google Drive. Homework is submitted to the learners own Google Drive folder, where the teacher has read and write access, to follow up the learners work. "The pupils know that we are able to review their homework at any given time, although we do not have the capacity to check every single pupils homework." When searching for software to use in their classes the most important criterion is that the software supports Feide, a national identification service for schools and scientific research, or Google-login. Having the learners keep track of multiple usernames and passwords is problematic. It is hard to evaluate software, as they are relatively similar at first glance, and no one product covers all desired features. "It would be best if one platform could satisfy all needs." A teacher is free to use whatever digital tool he or she wants, as long as it's free. If it is not, the purchase of the product needs to be approved by the administration.

The teachers do not perceive digital learning tools as distracting. "Our pupils regard PCs and tablets as tools and rarely get distracted by the many temptations of the internet. They are much better at this than us", one of them jokes. Learners are not able to bring the laptops home with them. Learners were previously allowed to bring the laptops home. This led to a high rate of malfunctioning machines.

The school recently changed learning management system (LMS) from It's learning, to Google Classroom, to Google Sites. The teachers said It's learning and Google Classroom restricted the teachers autonomy. They had to conform to the LMS "way of doing things". Google Sites lets them tailor the site to their needs. They point out that it requires a certain level of computer proficiency to use it well, and that it can be problematic for some of their colleagues to do without help. They feel current LMSs are poor at conveying information to students and parents. They would like an easily configurable dashboard to display calendar, homework, and other important information.

3.1.3 Preferences for a Future Classroom

Both interviewees agree that they would like some way to track their learners progress when doing digital tasks. The one interviewee spoke highly of the feedback given by Campus Increment. Which was used when practicing flipped classroom. Status of the learners answers (right/wrong/not answered). The Learners also had the opportunity to leave a comment, thoughts regarding the questions. The teachers considered this helpful feedback, when planning future lectures and class activities. It was emphasized that this was not used for grading purposes, only to get an overview of the progress of the individual learner and the class as a whole. Grading is a highly nuanced process which takes into consideration much more information then what is provided by current learning systems. The

other interviewee commented that it would be great to have the same system for his language subjects. Instances where automatic grading was not possible (free text answers), it would be well received with tools to assist the grading process. Like saving regularly used comments for reuse, and the ability to rapidly switch between learners assignments. “Today’s workflow includes a lot of clicking”. They both agree, too much clicking is a recurring trend in most of the digital systems they use for teaching.

When using Khan academy the mathematics teacher had noted his learners excitement and increased motivation when receiving points. The learners got a stronger sense of achievement by completing tasks and video lectures, and it motivated them to do more. The other interviewee had noted the same with the leaderboard in Quizlet, although it motivated some much more than others. Both were positive to points and leaderboards. The competition feature in Quizlet got high praise. They would like to see more gamification features in future learning material.

When it comes to privacy, the teachers trust products that are using the Feide login service and Googles education accounts. Although they do admit to not think to much about data protection.

3.2 Questionnaire - Digital tasks

The main goal for this questionnaire A was to use teachers pedagogical experience to evaluate the learning efficiency and motivational contributions of various gamification elements. Since it is up to the individual teacher what tools to use in their classrooms, it is important that they believe the tools they use contribute to learning process. The questionnaire was also used to uncover what kind of digital tools, and how often teachers are using them in their pedagogical practices, along with the availability of digital devices in their classrooms.
The questionnaire was sent out to an even distribution of primary schools, secondary and upper secondary schools, and evenly distributed geographically throughout Norway. After a two week period there were 29 responses. This is not enough data to draw any definite conclusion, though it does give some indication of teachers opinions on the different gamification elements.

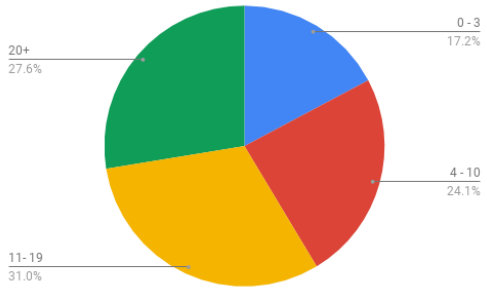


Figure 3.1: Years of experience among respondents in questionnaire

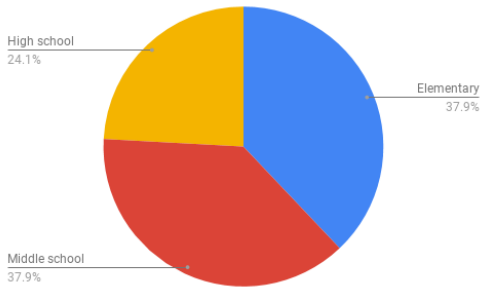


Figure 3.2: School level distribution among respondents in questionnaire

3.2.1 Findings

The results show a high availability of computers and tablets among learners. Almost two thirds of the learners have access to their own device. Although 14% of teachers have three or more learners per device. Digital devices are mostly used as a writing tool, to access LMSs, and to read digital text books. Only a few teachers is admitting to use digital assignments. There is however a significant variation in teachers opinion on quality and availability in digital resources, and how this is limiting their use of digital resources in their classrooms.

There were four clear favorites among the gamification elements proposed. The absolute favorites were adaptive difficulty and spaced repetition. They scored well on both motivation and learning efficiency. “Experience points”, was the only traditional gamification element the respondents were decisively positive about. The teachers wanted progress tracking on their learners. Although only moderately positive to the learners having access to their own progress tracking. The ability to create their own assignments was something that teachers were almost uniformly positive to.

For the rest of the gamification elements proposed in the questionnaire, the respondents were moderately positive, except for two. The teachers were slightly negative towards leaderboards and the loss of points for abstaining from completing assignments. That the respondents are positive to individual- and team competitions, while negative towards leaderboards and point loss, may suggest a bias against explicit negative reinforcement. A possible trend could be seen in those who teach younger children, grade 4-7, but also from grade 1-3. They awarded team-based competition a slightly higher score as a motivational tool. If this trend were to hold with a more solid data foundation, one potential reason could be that team-based competitions are more aligned with a younger school audience as it allows for playfulness and activity.

Those teaching grade 1-3 rated the motivational benefit of “freedom to explore the curriculum” higher than that of their colleagues teaching older children. They also ranked the receiving of achievements as more motivational than their colleagues. It may be that those who teach younger children need to actively trigger the extrinsic motivation in their learners; The children may need more guidance to adapt to the school system. But again, to confirm such trends more data must be collected.

3.2.2 Concerns

The questionnaire contained free text answers where respondents could elaborate their answers if they wanted. Eight respondents expressed concerns that some of the gamification elements would only benefit the well performing learners, while it may have a negative effect on low performing learners, affirming their poor performance. Gamification elements promoting competition was explicitly mentioned as detrimental to motivation of low performing learners.

3.3 Interview with Professor of Education

The objective of the second interview was to gain insight into the education of teachers, and what education teachers get in usage and evaluation of digital systems. A semi-structured interview of an associate professor of education was conducted. In the initial part of the interview it was uncovered that the interviewee had experience with digital assignments, and was advising a master thesis that was developing better assignment formats.

- What education does the school provide in terms of evaluation and use of digital educational tools?
- What digital tools are presented to students of pedagogy, if any?
- Does the school provide follow up education of digital tools, and evaluation of digital tools to teachers?

To his knowledge there were only one course that explicitly included teaching of digital learning tools. It was however exclusively and mandatory for pedagogy students specializing in maths for grade 5 to 10. A course in mathematical modeling. As a part of this course students are to find digital tools and assets that can be used in maths classes, and write reviews of it [41]. Other than this only Excel spreadsheets and Geogebra, a digital graphing tools is presented to the students. Theses types of tools are mandatory in Norwegian secondary school curriculum.

There were recently given a grant to the interviewees department from the Norwegian Department of education to educate professional teachers in the use of digital tools. Although he did not know what it entailed.

During the interview when talking about assignment formats, the interviewee brought up that he had in young learners observed that they often clicked frantically in an effort to maximize the positive feedback given over time. Carefully carrying out the assignments resulted in a higher percentage of correctly solved tasks, but reducing the number of correctly solved tasks. This is a perfect example that gamification elements cannot be naively applied. They need to be carefully implemented and tested to ensure that the desired behavior is in fact the behaviour that is being reinforced. In relation to this the interviewee also brought up Erlwangers' Benny [42]. In short Benny is a 12 year old student perceived by his teacher as proficient in maths, compared to his class mates. However Benny has misunderstood key concepts in fraction and decimal points. Although he believes he is understanding the concept, and performing the problems correctly. Benny knows that multiple fractions can be equal despite the numbers being different. He therefore thinks when he gets an answer wrong, it is the teachers fault for blindly checking his answer against the solution answer. Which he thinks is equal to his answer, but not identical. This is an important note to have when developing digital assignments that does not explain why the answer is wrong.

When describing the results regarding competition, section 3.2, from the survey he was not surprised. He said that Norwegian teachers often have an ambiguous relationship with competition in school. Explaining that it may be that there is a feeling that competing academically with fellow learners does not promote a nurturing learning environment. And that it is better to compete with oneself in an attempt to achieve better results.

Chapter 4

Related work

So far theories surrounding gamification, motivation and pedagogy have been presented, and now it is pertinent to delve into the world where this comes together. Hence this chapter will look at three case studies on gamified learning systems. It will also cover a small selection of gamified learning systems relevant to the public school.

4.1 Gamification in recent literature

This section will look at what has been done with gamification, regarding education, inside of academia within the last decade.

4.1.1 Case Studies

Q-learning-G

In 2012 Spanish researchers did a case study on the effects of gamification and digitalization through the platform "Q-learning-G" [43]. This platform was created as a learning tool to assist part of a C programming course. The case study's hypotheses was:

1. Students will work beyond the learning requirements of the course.
2. Students will change their learning strategy once they achieve the learning requirements of the course.
3. Students will gain knowledge of C-programming language by using the Q-Learning-G platform

The platform contained three types of activities the students could partake in; work, planning and social. In the work activity the students were tasked with answering questions. The questions consisted of either multiple choice which was automatically graded, or free text questions which was graded through peer grading. The tasks were split into ten sub-groups. The students had to get ten points in each sub-group to pass. The planning activity contained a list of tasks, and the amount of points the student would get by performing them. This was named "stock market".

The value of a task was calculated by how many times this kind of task was completed relative to the others. The social area was a small forum where students could communicate with each other, teacher assistants and teachers.

Gamification elements utilized by the platform:

- The students earned **points** by completing tasks. These points contributed to the mastery level in sections of the course. Mastery in course sections contributed to the final course grade.
- In addition to points, students got "**phrases**". These are quotes from famous IT personas. When all quotes from one person was attained, the student got a badge of that person displayed in their "trophy case".
- A **leaderboard** of top n students with respect to points earned and phrases collected.
- "**Stock market**" was a dynamic list of tasks and their value. Doing one task deflated its value relative to the other tasks. This provides incentive to vary task selection, it works as a primitive dynamic difficulty mechanic, and promotes autonomy in the learning process.
- Students could at any time get **feedback** on their course progression.

The study consisted of a pre-test, a post-test, and a short questionnaire about the participants impressions of the system. This data and the data generated by student interaction with the platform was evaluated through the use of "the sequential explanatory design method". The study showed that students continued to use the platform to master topics after the mandatory requirements were reached. Collecting all remaining badges were a major factor according to the questionnaire. Another dominating factor was to help fellow students by grading assignments. There was mixed feelings about the leaderboard. Though motivating for a few students, others felt ashamed of their ranking, and some were indifferent.

Most of the students met the required 100 points to pass the course. Of those half put in more than 29% more effort than the minimum requirement, and a quarter made an effort over 60%. The study concludes that the platform motivates some, but is not appealing to everyone. The pre- and post-test shows that the platform did help the students learn. The study did not however have a control group, so it is impossible to say if the platform worked better than traditional assignments.

Gamified learning intervention

A paper by Buckely and Doyle was published in 2014 described a study done in higher education on the topic of the national tax system (Ireland). The aim of the study was to empirically investigate *"the impact of gamification in a web-based educational context"* [10]. The learning platform in use was a group decision-making system, also know as a prediction market (PM), modified to suit an educational context. The paper presented seven hypotheses:

1. H1: Students' general knowledge of the national tax system will be improved as a result of the gamified learning intervention.

2. H2: There is a positive correlation between intrinsic motivation to know and participation
3. H3: There is a positive correlation between intrinsic motivation towards accomplishment and participation
4. H4: There is a positive correlation between intrinsic motivation towards stimulation and participation
5. H5: There is a positive correlation between identified motivation and participation
6. H6: There is a positive correlation between introjected motivation and participation
7. H7: There is a positive correlation between external regulation and participation

The study was conducted as part of a taxation module at undergraduate level. The result of the students activities went towards 10% of their final grade. The learning outcome corresponds to H1; a boost in the general knowledge of the the national taxation system. The students task was to predict the measures that would be taken in the national budget for 2014. The case study consisted of a pre- and post-survey of ten free form general knowledge questions. For the gamified learning platform the students were provided with 5000 virtual cash. The students invested their virtual cash by predicting the outcome of 14 questions(*stocks*) throughout the course. This was to stimulate the students to seek out information on the national budget on their own to make the best possible investments.

Through a literature review four gamification elements were identified as suitable in a learning context. The PM's main objective was to raise the general level of knowledge on the topic of the national tax system in Ireland. The students interacted with the PM through buying and selling stocks, which translate into **specific rules** for the students interactions. A PM is in itself a **reward system**, a correct prediction returns an influx of funds and an incorrect prediction leads to a loss in funds. Being a group decision-making system, a PM provides feedback continuously to those who interact with it and so deploys **rapid feedback cycles**. Everyone's actions contributes to determine the value of the stocks, and consequently participants can always re-evaluate their actions. Buying and selling stocks according to the information available. If many want the same stock the price will rise, and vice versa. A PM is naturally **competitive** as " in order for one participant to make gains, another must suffer losses" [10]. The competitive element in the gamified learning platform was exasperated by leaderboards and a ranking system.

Overall this study concludes that gamification does have the power to increase engagement and participation in students. Nonetheless, it emphasize that gamification is not an easy fix and that the effect of gamification is dependent on a student's type of motivation. Hypotheses H1, H2, H4 and H5 were found to be true and the remaining hypotheses H3, H6 and H7, were not supported. Regarding H1 Buckley and Doyle felt "confident in ascribing some of the observed [learning] effect to the gamified learning" [10] platform. The study suggests that students who are intrinsically motivated to know and towards stimulation have better effect of gamification. The proposed reason for this is that the competitive elements of leaderboards and ranking systems as well as the uncertainty and thrill of forecasting events are similar to gambling. Through hypothesis H5 this study indicate that extrinsic motivation by identification is a viable type of motivation benefiting gamified learning platform, given that it is suggested by a

mentor-type person.

The only type of intrinsic motivation that seemed to have less than a positive effect in the gamified learning platform was motivation towards accomplishment. A factor in this result may have been the unfamiliarity of the new assessment style. Furthermore, those who were extrinsically motivated, hypotheses H6 and H7, reported a feeling of unfairness regarding the assessment style as it had no obvious recipe for success and they disliked the competitive element.

In summary, this study demonstrates that gamification is viable in an educational context. However, for everyone to benefit one must consider how people are motivated and accommodate gamification elements thereafter.

Engaging Engineering Students with Gamification

Barata et.al. [44] conducts a comparative study in the MSc course "Multimedia Content Production". The comparison is between two classes doing the same course one year a part. The first year a plain version of the LMS Moodle was used. The second year a set of gamification plugins were added to Moodle. The gamification elements in the plugins were points, achievements and leaderboards. They named the points XP for experience points. The students could earn 10% of their final course grade by earning achievements using the Moodle plugin.

- **XP** was awarded for every activity in class. For getting achievements, attending lectures, completing quizzes, for homework and lab-work. Reaching certain XP thresholds earned the students **titles** like: novice, "Starting to see the light", "Taking your first Steps", etc.
- **Achievements** was also awarded for many of the same activities that earned the students XP. In addition they got achievements for participating in the class forums and going through the lecture slides.
- **Leaderboards** show a list of the top performing students in terms of XP

The comparison shows up to eight times as much activity on the forums for the gamified course, an increase of 40% in lecture slide downloads, and an increase in lecture attendance from 81% to 92%. Even though the student activity in the course increased, it did not change the grade average from the previous course. The students were generally positive to the gamification, and strongly agreed with the course being more motivating because of the gamification, relative to other "traditional" courses. The students did not feel that all achievements were as useful. For instance, earning an achievement for posting on the forum resulted in a large amount of low quality posts. An interesting remark by this paper is the importance of reward engineering. Reward engineering is the act of balancing rewards distributed by the system, so that desired behaviour is encouraged. This includes things like making sure that reward is proportional to challenge throughout the system, and that reward cannot be acquired through cheating. In this paper, it was evenly distributing the rewards across time. The system had a finite amount of reward the learners could earn. When the learners had collected all available reward, there were no longer any incentive to

use the system. The authors hypothesized that this uneven reward distribution exited students in periods of high reward, mostly in the beginning of the course, which made periods of low reward more disengaging.

4.2 What Exists Now

Four digital learning systems were selected for the purpose of describing how gamification is used in a educational context. The primary basis for the selection was usage and relevance to the Norwegian school system. In 2017 the Norwegian government presented a strategy to digitize the educational system, from year 1 through year 13 [45]. Part of this strategy is to stimulate development of digital learning systems and digital learning resources. An interview with teachers revealed Kikora, Khan Academy and Campus Inkrement as digital learning environments that is in use. In addition to these three, Salaby was selected. Both Salaby, Kikora and Campus Inkrement are backed by well established institutions in Norway [46, 47, 48]. Kikora is a Norwegian startup with the publisher Aschehoug as a major investor and Salaby is developed by the publisher Gyldendal and is supported by the Norwegian Directorate for Education and Training. In fact Salaby and Kikora was awarded funds in the name of the strategy to digitize the educational system. Campus Inkrement is also a Norwegian technology startup and has a collaboration with Cappelen Damm. Gyldendal, Aschehoug and Cappelen Damm are all publishers that have a long history of providing learning material in the Norwegian school system. [49, 50, 51]

Another important factor was how easy it was to gain access to these digital learning systems. All except Khan Academy use a license-based purchase model. Salaby, Kikora and Campus Inkrement use Feide, the national login solution for education and research in Norway, as their login service. NTNU had full licenses for both Kikora and Salaby. NTNU did not have a license for Campus Inkrement, but Campus Inkrement offered a free trial of part of their material. As for Khan Academy, with an international audience, learners may gain access through a Google account, Facebook account, or create a dedicated account on Khan Academy with an email.

4.2.1 Khan Academy

Khan Academy started in 2008 by Salman Khan as a means to tutor family members in math over the internet. When popularity for his videos grew he published them on Youtube [52]. Khan Academy is today a comprehensive learning platform with many courses in maths, science and other fields with more content on the way. Khan Academy is free of charge and does not require a user profile, though some features like progress tracking are not available without one. Using Khan academy both privately and commercially is also free.

Structure

Khan Academy provides full freedom to learner to choose courses and difficulty level. The courses on Khan Academy are divided into categories e.g. math, science and engineering, computer science, arts and humanities, etc. The categories are populated with courses e.g. algebra 1, geometry, algebra 2, etc. Each course is split into concepts.

Algebra for example is split into “solving equations”, “solving inequalities”, etc. Each concept is further divided into units. These units contain video lectures, articles and assignments. There are small quizzes regularly in between the units, and a final test to end the concept.

Tasks

Khan Academy uses for the most part multiple choice as a format for practise assignments and quizzes, with the exception of some free text answers and a graph tool. The multiple choice assignments have two to four alternatives. Assignments are partially randomized so they can't be memorized. Numbers, graphics and text seems to be drawn from a database and combined to make up an assignment.

If the learner needs help with an assignment the learner can watch a related video lectures, or the assignment can be explained through step by step hints. The number of hints vary. At first the hints are general, but become more specific gradually. By choosing to get help as described above, the learner forfeits the right to earn points and experience on that particular assignment. See Figure 4.1.

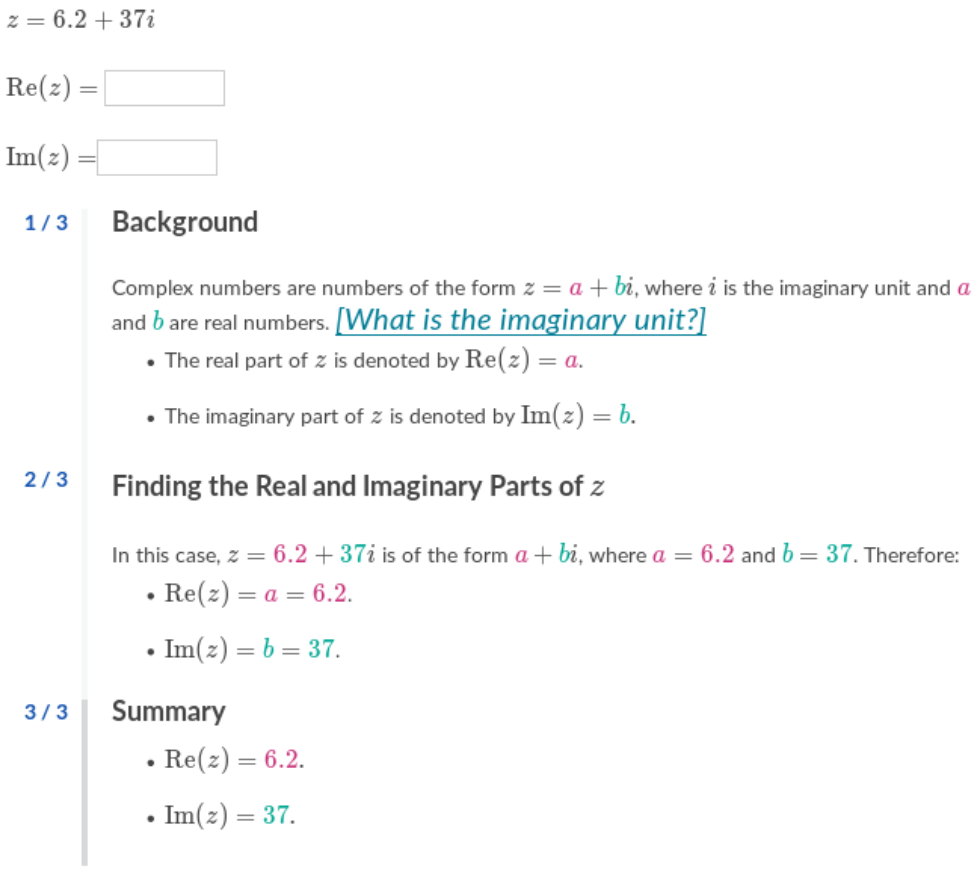


Figure 4.1: Step by step hints in Khan Academy; from general to specific help

How is it gamified?

The complete gamified version of Khan Academy is mostly reserved for the courses up to upper secondary school level. E.g. 1st. to 8th. grade math, world history and algebra 1 & 2. This section will deal with the complete gamified version.

Khan Academy utilizes a range of gamification techniques. Registered users at Khan Academy are well-informed of their learning process and learning progress. Figure 4.2 displays a user profile at Khan Academy. This will reveal the more obvious and heavily featured gamification elements put to use by Khan Academy.

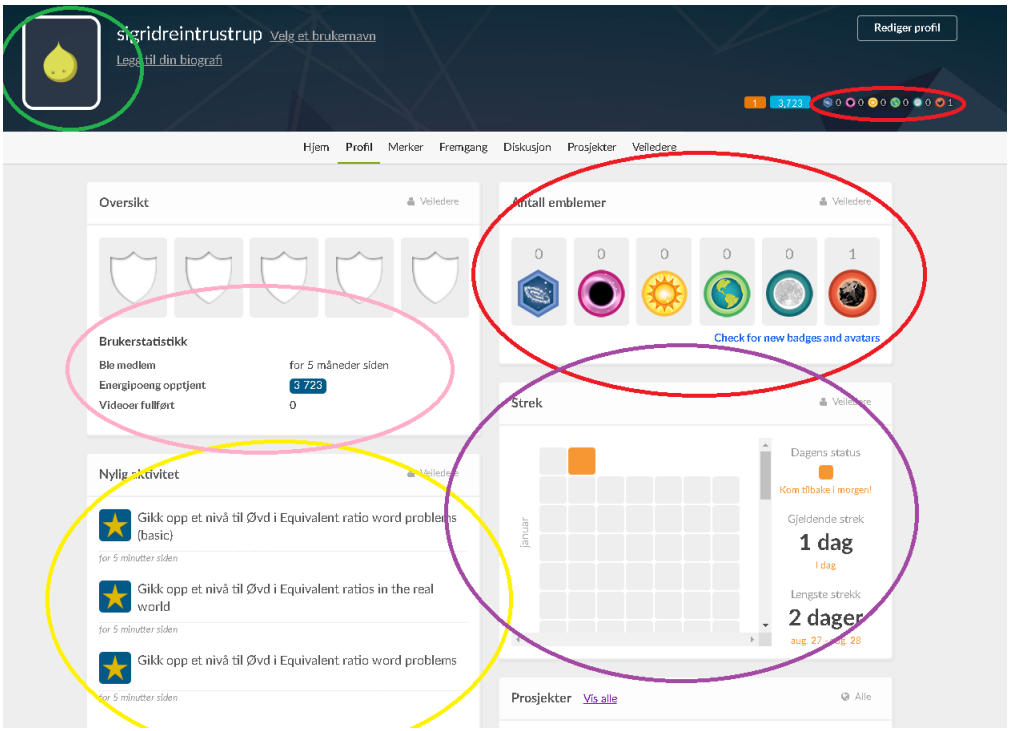


Figure 4.2: User profile at Khan Academy.

The user profile presents the learner with an overview of their badges (circled in red), recent learning activity (circled in yellow) and their level of activity over a longer period, highlighted by current streak and longest streak(circled in purple). Also energy points earned and videos finished (circled in pink) can be found in this view. In the top right corner (circled green) there is an avatar, which the user may change according to their preference. The banner in which the avatar is placed in is also possible to change. Deciphered from this the gamification elements are points, badges and customization.

In addition to energy points, Khan Academy uses another point system; mastery points. Energy points are mainly earned by watching video lessons. While mastery points are earned by completing assignments correctly. However, a small amount of energy points are awarded to the learner even if the assignment was unsuccessful. This is to keep from discouraging the learner too much. Figure 4.5 shows the scale after which mastery points are awarded when doing assignments. 75% correct gives 50 points and the learner is considered *Familiar* with that unit and full score

gives 80 points and the learner is considered *proficient*. An extra 100 points are earned for each assignment in a unit when taking a quiz or the final test in the concept.

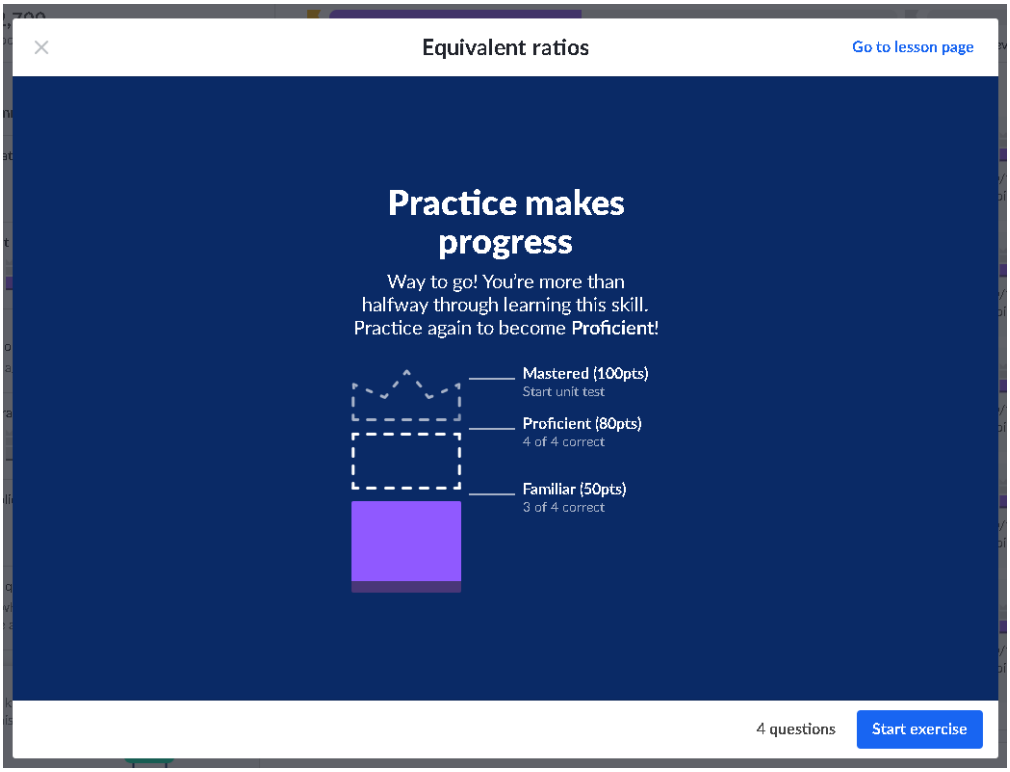


Figure 4.3: The road to mastering a skill is built on mastery points.

The main goal in a course is to have mastered every concept in the course. The progress towards mastering a course is documented to the learner through the mastery points, the total for the whole course and for each concept. See Figure 4.4.

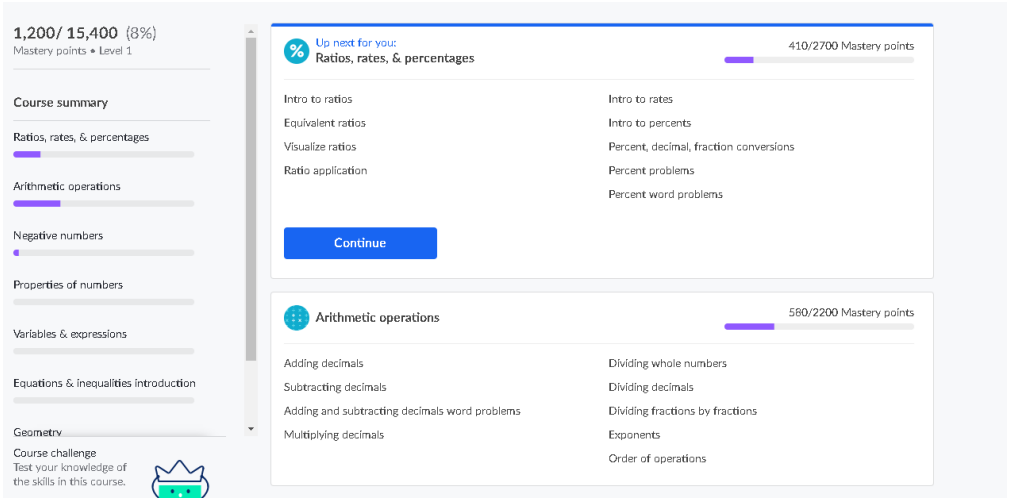


Figure 4.4: Earn mastery points to become a master.

Furthermore, see Figure 4.5, inside each concept a level bar is included. This is visible every time the learner finishes an assignment or goes between video lessons, articles etc.

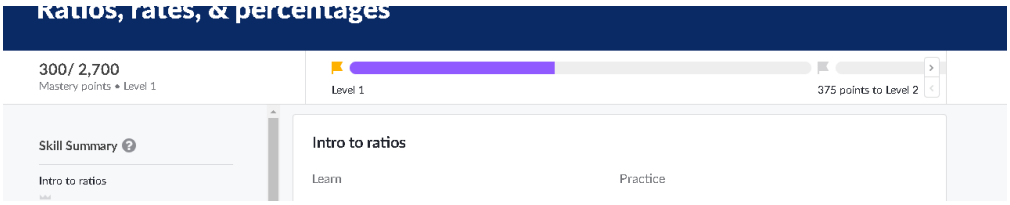


Figure 4.5: Level bar inside each concept displays the amount of mastery points earned and how many to go to level up.

The energy points are there to encourage the users to take advantage of the video lessons, and the mastery points are there to encourage the users to practice what they learned in the lessons. Mastery points are earned for each individual course. The value of the mastery points, aside from attaining more knowledge, lie in leveling up and gaining badges. While energy points unlock the evolution of avatars, backgrounds, and some badges as well.

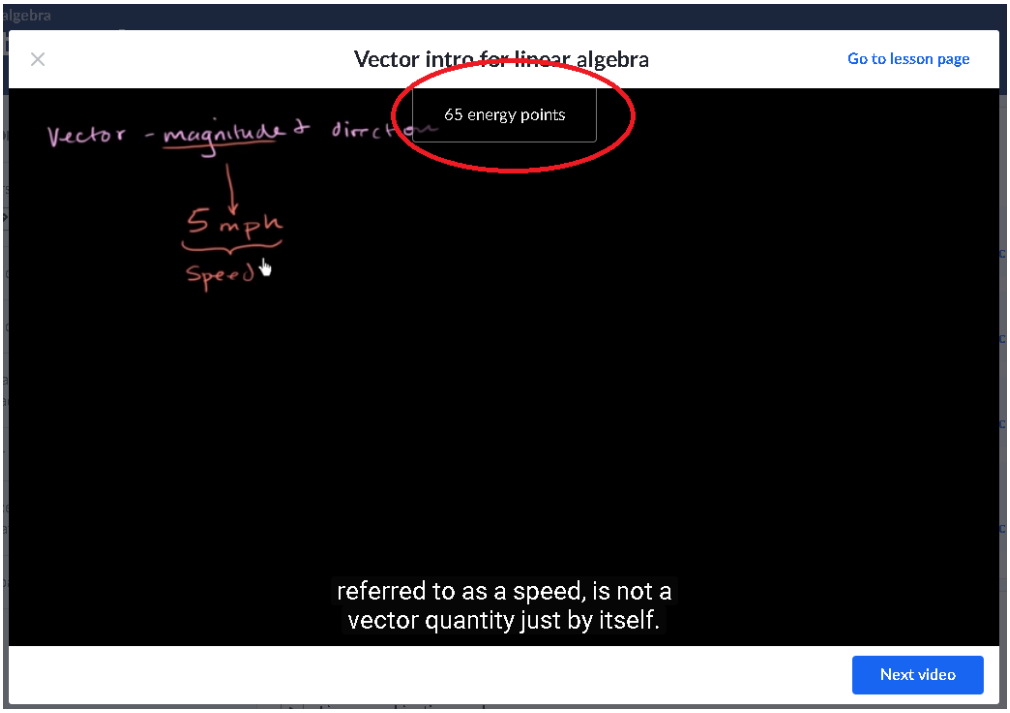


Figure 4.6: Energy points are visibly increasing while watching video lessons.

The badges are ranked by difficulty. Which gives the more difficult ones more prestige, see Figure 4.7. The idea is that higher value leads to a greater feeling of satisfaction when gaining these badges. The learner can see the conditions of the badges, which means they can actively collect them. The black hole badges are unknown, unlike the rest of the available badges, which makes them Easter eggs like described in chapter 2.3. Even though it is uncertain if Easter eggs have any valuable effect on learning, it is fun and exciting to be on the look out or "on the hunt" for these Easter eggs. Which may contribute to more alert and focused learners.

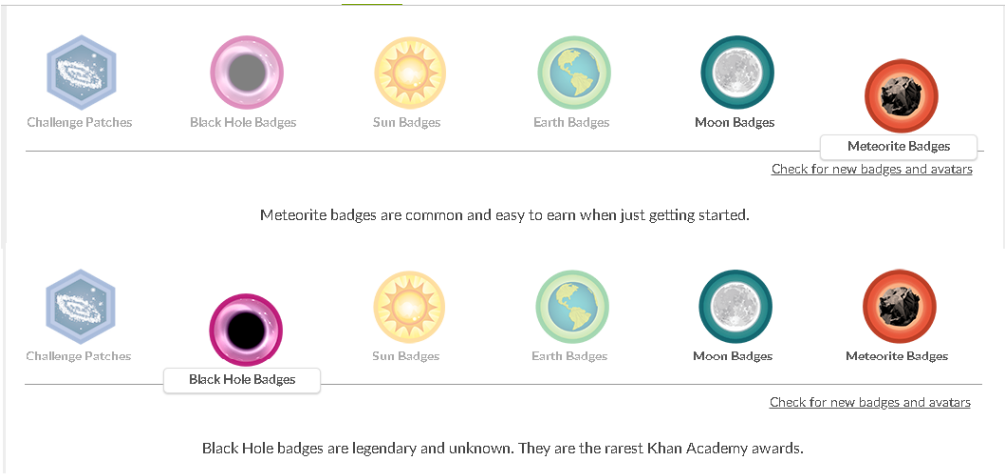


Figure 4.7: The meteorite badges are easy to obtain, whereas the black hole badges are the rarest.

As mentioned earlier the learner can choose an avatar and preferred background. The available options when it comes to the avatar and background are closely attached to the energy points and badges a learner has obtained. Furthermore, the learner can choose how they appear to the community on Khan Academy by adding a short biography and nickname to their profile. Only friends and teachers can see their real name, and even that is editable. See Figure 4.2. This way the learner can personalize their learning profile and put some personality into it.

Moving along to the gamification of the assignments. When an assignment is answered correctly a little positive sound effect plays and a small firework is displayed in the bottom right corner, giving immediate feedback to the learner that is was correct. This is in addition to the written confirmation. Likewise, a little tune is played along with fireworks when a whole set of assignments are done, and a display of the points earned and potential badges obtained.

Math missions are assignments, sometimes video lessons, where the difficulty level is personalized to the individual learner. In other words, Khan Academy uses adaptive learning to a degree. A mission is designed to have broad coverage of the content of the relevant course. When starting a mission a quiz is taken to determine which assignments to recommend to the learner. The learner can add skills they want to practice themselves. Points and badges are awarded as usual, and contribute to the overall mastery level of the course. When every skill in the mission is mastered the mission is over.

Khan Academy is a community of people learning, teaching and exploring knowledge. Every video lesson allows questions and comments, and has a section for sharing tips and tricks. Helping or teaching others is in itself a reward for many. Learners are permitted to up-vote or down-vote other learners comments, making it a democratic arena.

Using the terminology from chapter 2.3 to summarize the gamification elements used by Khan Academy:

- Points: Energy points and mastery points.
- Badges: Meteorite, moon, earth, sun, black hole and challenge patches.
- Customization: Choose avatar, nickname and short biography.
- Sounds: A tune for correct answers and for completing sets of assignments.
- Easter eggs: Secret conditions for gaining black hole badges.
- Quests: Math missions.
- Sharing knowledge: Learners ask and answer questions, vote on answers, evaluate other learners contributions.
- Adaptive learning: Math missions are personalized to each learners mastery level.

Khan Academy for teachers

Khan Academy has a feature that lets teachers use Khan Academy for their classes. By inviting their learners to their Khan Academy class, they can issue home work, track individual learners progress or whole classes. Through this progress tracking the teacher can see what needs repetition and whats is sufficiently understood.

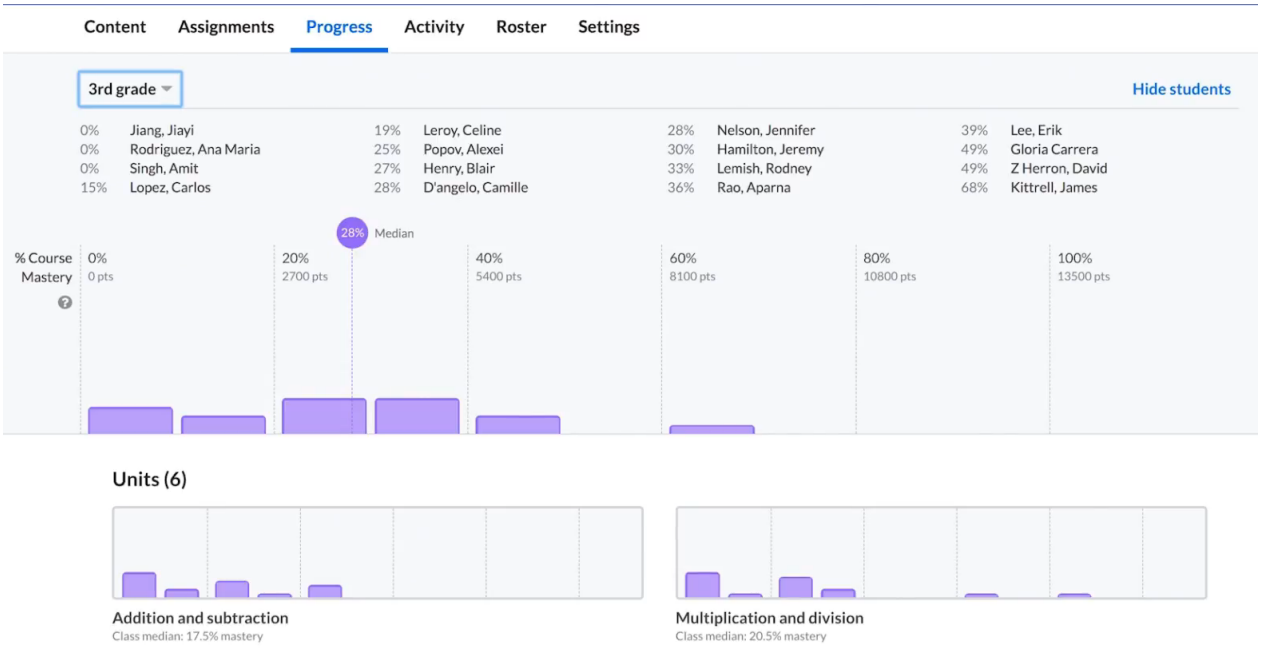


Figure 4.8: Khan teacher dashboard showing over all progress of the entire course and units for the entire class, and progress for the individual learner.

4.2.2 Kikora

Kikora is a Norwegian web-based math assignment platform. It's mission statement is to cover the entire Norwegian public school curriculum in mathematics by 2020. Kikora requires a licences per learner to use. A license costs between 75 and 150NOK per learner per year depending on age. The learners login using Feide.

Structure

Once logged in the learner is displayed a list of assignments given by the teacher. The learner can also choose to do assignments from anywhere within the public school curriculum. When a course and a topic has been selected, the learner is presented with assignments sequentially, but is free to jump to anywhere in the course's assignments.

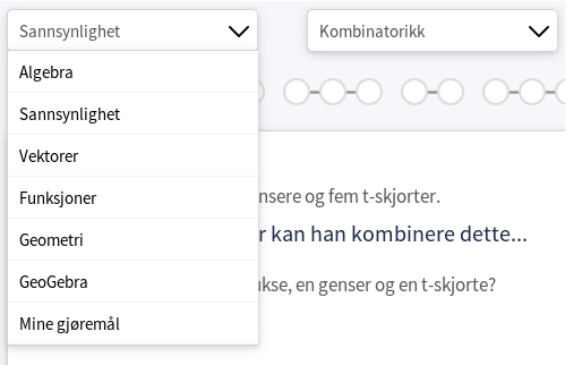


Figure 4.9: Kikora curriculum navigation

Tasks

Kikora uses a composition of the task formats text, equations and graphics, depending on the problem type. To answer questions Kikora uses either multiple choice, text input or a GeoGebra applet. The text input is sophisticated compared to the other candidates. It uses Mathqull to render mathematical notation as you type. The text input lets the learner submit partially solved problems for evaluation, allowing the learner to see where in the problem solving process errors occur, and allowing the teacher to see where in the process the learner is struggling 4.10. GeoGebra applet is a graphing tool that lets the learner draw points, vectors and shapes. The functionality of the applet is restricted to functionality needed to solve the given problem.

How is it gamified?

Kikora is mostly a digitalization of mathematical assignment textbooks, there are however a few gamification elements present.

- **Trophies** are given to the learner upon solving a problem. Number of trophies earned is displayed on the front page.
- **Adaptive difficulty**. In Kikora it is up to the learner which difficulty level to choose. The learner can select from number paths. A path being a set of assignments. The number of available paths depends on the selected course.
- A **progress bar** is used to keep track of where the learner is in a set of assignments. It also doubles as a navigation tool, letting the learner jump freely between the assignments in the current set.

- **Certificates** are mentioned on the front page. It is however unclear how they are obtain and what they are.

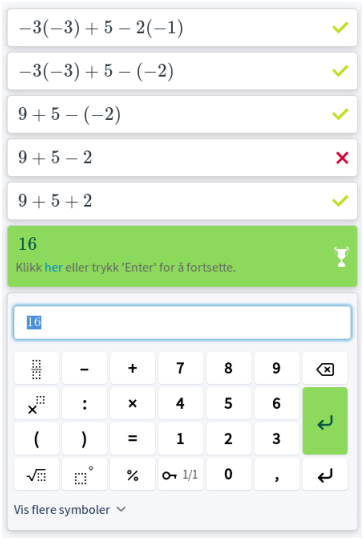


Figure 4.10: Kikora's text input evaluating partially solved problems

Kikora for teachers

The teachers have insight into everything the learner does in Kikora. From a general overview the teacher can see how many assignments the learner has done in each difficulty path, how many correct partial answers the learner has submitted and number of incorrect answers the learner has submitted. Also, how many times the learner has requested a solution, and how much time the learner has spent on the assignments. The teacher can organize this information in as much detail as desired, from the learner's individual assignments to an overview of a whole course.

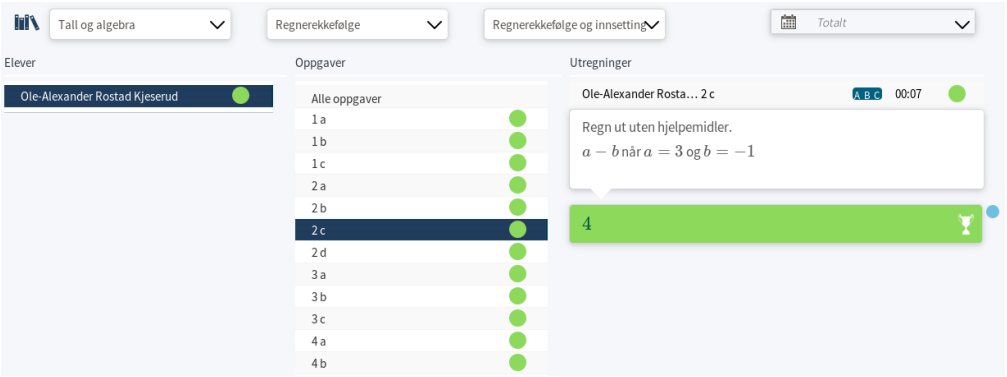


Figure 4.11: Kikoras teacher overview of students completed assignments

4.2.3 Salaby

The publisher Gyldendal has in cooperation with The Norwegian Directorate for Education and Training developed Salaby. Salaby is a web-based "learning universe" for children in kindergarten and children from 1st grade to 7th grade. It provides resources for most subjects. Those resources includes videos, games, tests, tasks and quizzes. In addition to the main resources they also provide a version of Salaby that is facilitated for children who use a head mouse, switch control or other alternative controls. Not all content is available in this version. It is also facilitates for children whose first language is not Norwegian. Additionally, the “learning universe” includes printable templates and instruction booklets on games for children, such as clapping and singing games. A license is required to access Salaby. Schools and kindergartens pay per learner. From 90-115NOK plus taxes depending on how many learners. A license is valid for 12 months.

Structure

When logged in the learner chooses grade, then subject and learning activity. See Figure 4.12 and Figure 4.13. The learners are free to explore all activities at all levels. Salaby itself does not supply the full curriculum for the Norwegian public school, rather learning activities to use as part of the overall education. Learning activities are divided into difficulty level as seen in Figure 4.12. It is up to the learner or the teacher to find suitable tasks within the chosen range of grades. Each subject has many topics and topics have several activities. E.g. In the subject mathematics there is a topic called concepts, and in concepts there is an activity called riddles. Topics may have sub-topics. Hence, navigation throughout Salaby is a tree structure requiring many clicks to begin an activity.

Figure 4.12: Excerpt from Salaby: Start page for school children.

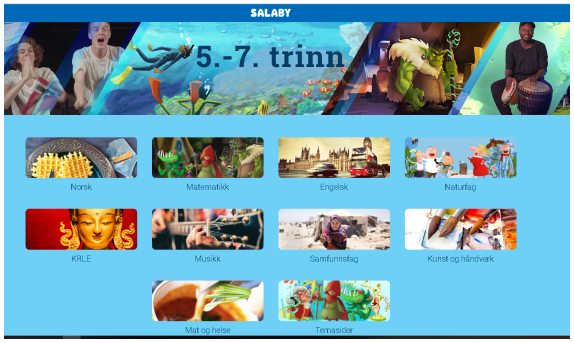


Figure 4.13: Excerpt from Salaby: Subjects available for 5th to 7th grade.

Tasks

Tasks come in several different formats within Salaby. Tasks are integrated into mini-games and digitalized textbooks. Most tasks come in the shape of multiple choice, where there are three or four options, see Figure 4.14 and 4.15 below. Several mini-games utilize drag and drop to match words, place numbers in math problems and sounds (e.g. accents, instruments). An example is the mini-game where the learner has to match English accents to the correct countries by dragging the characters across a world map. Frequently used task formats in Salaby are class quiz, true or false statements, "test yourself"-type quizzes, word clouds of terminology (with definitions/explanations), point and click and text/number input.

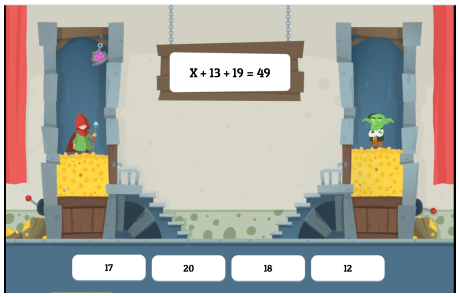


Figure 4.14: Excerpt from Salaby: Equation task with a story. The characters in the background is recurring. The red-hood character is the learner who is fighting the evil green gnome by solving his equations.

Figure 4.15: Excerpt from Salaby: A simple multiple choice task in the subject Norwegian.

The feedback given to the learner when completing tasks comprise of whether it was right or wrong. The learner is not told where in error lies and is not told why it is wrong. Meaning the learner will have to use the trial and error method to find the right answer. This is how feedback is generally given by Salaby, however for drag and drop tasks/mini-games immediate feedback is given; the object being dragged to the wrong place bounces off the area.

How it is gamified?

The "learning universe" of Salaby consists of many small tasks and games. They are mostly independent, the exception is: Game of Gnomes. It is a series of cross-disciplinary mini-games, about mathematics, science and social science, where the goal is to find seven pieces that complete an amulet.

The first gamification element that is apparent is the recurring theme of characters and drawing style. For each range of grades the characters differ. Figure 4.12 shows how the grades are divided and their respective characters. Not every task or mini-game include these characters and their theme. Many tasks and mini-games have their own independent theme befitting the teaching goal. Game of Gnomes has an overhanging theme of the good versus evil. The learner, being the good, will have to defeat seven evil gnomes to fulfill the main goal of obtaining all the pieces of an amulet.

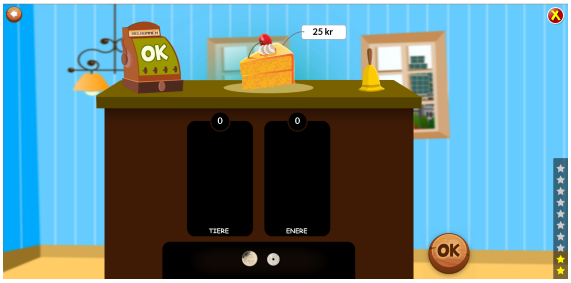


Figure 4.16: Excerpt from Salaby: Learning the Norwegian currency through buying cake.

Figure 4.16 illustrate the use of independent themes. It depicts a mini-game intended to teach the learner about the Norwegian currency. Here the theme is buying cake in a cafè. The learner has to hand over the right amount of coins to buy the piece of cake.

In the bottom right corner of Figure 4.16 is another example of gamification; gold stars. They work as a progress tracker and as an indicator of correct answers. Furthermore, for correct answers the gold stars are accompanied by a little tune. Whereas for wrong answers there is no star nor tune, and the learner will have to do extra tasks equivalent to the amount done wrong.

Salaby for teachers

Salaby "lærerstudio" provides teachers the ability to generate playlists of learning material from Salabys content to use in lectures or assign to learners as homework. Additionally, teachers can create custom quizzes and they have access to other class activities through "lærerstudio", both digital and non-digital.

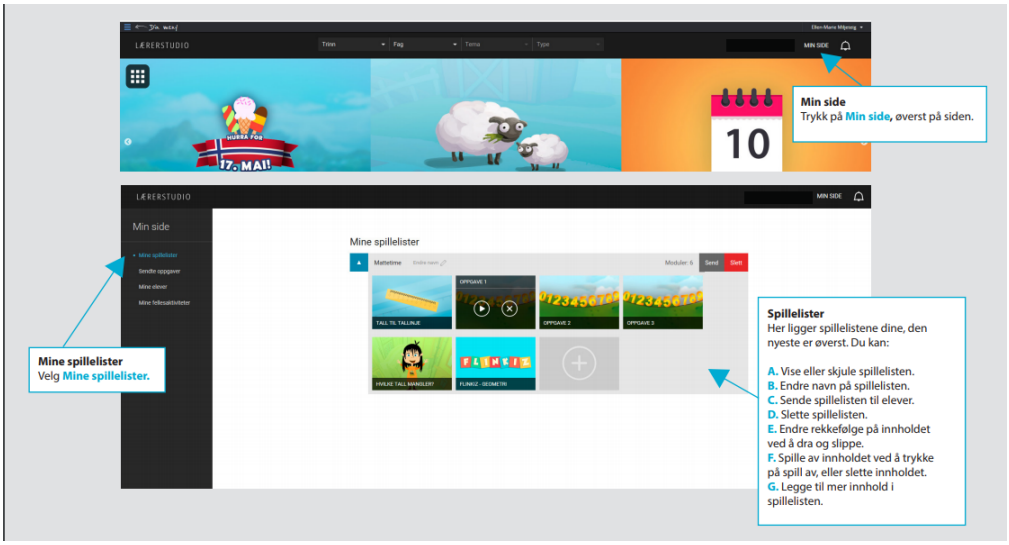


Figure 4.17: Salaby "lærerstudio": teachers dashboard with generated playlist[2]

Figure 4.17 above is an excerpt from the Salaby "lærerstudio" user manual. Teachers may organize learners in virtual classrooms, and assign homework to individual learners or whole classes. Below, in Figure 4.18, is an illustration of a teachers overview over who have done their homework. Status of completion is the extent of detail a teacher is presented with regarding each learners homework.

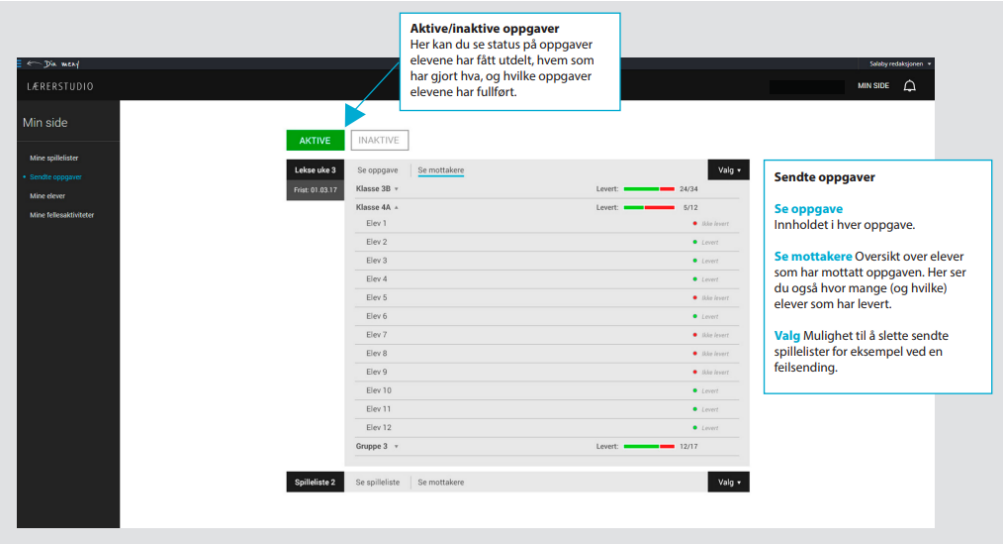


Figure 4.18: Salaby "lærerstudio": teachers overview of each learners homework[2]

4.2.4 Campus Inkrement

Campus Inkrement is a Norwegian based commercial learning platform founded in 2010. It is “a learning platform especially suited for flipped classroom.” Flipped classroom is a pedagogical strategy where what is considered homework in traditional education is done during class, and the instructional part of the class is done home beforehand. The instructional part is usually done through the use of online resources like videos.

Structure

Campus Inkrement has modules in primary school maths, secondary school maths, science and home economics, and upper secondary school maths. Each module is composed of videos and tasks. The modules are modeled after a textbook, so a sub-chapter in the book will correspond to one or more videos in the same sub-chapter in the module structure.

Tasks

The videos are between one and five minutes long, followed by a set of multiple choice questions related to the preceding video. See Figure 4.20 for example. The questions are static and few, intended for control purposes, not practice. The learner also has the opportunity to answer self evaluation questions. Letting the teacher know how well the learner understands the material, and if the learner has any questions.

How is it gamified?

The only two things resembling gamification on Campus Increment is the progress tracking in the sub-chapters, see Figure 4.20, and the course progress tracking, see Figure 4.19.

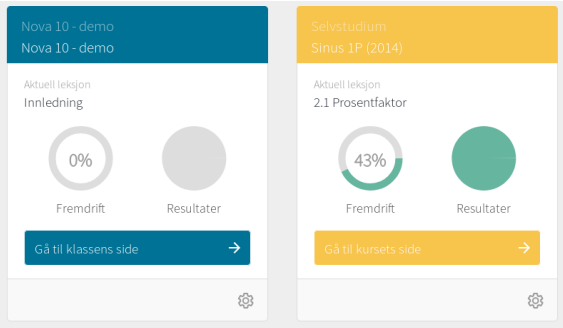


Figure 4.19: The progress tracker on the course overview page of Campus Inkrement.

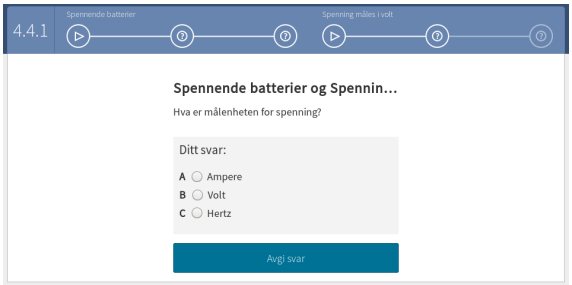


Figure 4.20: A typical task on Campus Inkrement.

Campus Inkrement for teachers

The teacher and the learner have access to the learners statistics, how much time the learner has spent on a sub-chapter, status of videos (not started/started/completed), and status of the questions.

Chapter 5

Development of the prototype

This chapter will cover what features and design decisions that are included in the prototype and why they are included. The purpose of the prototype is to serve as an example of what this kind of system can look like as a whole, how the individual parts can be implemented and how they can be put together. Mathematics assignments were chosen as a case, as it is relatively straight forward to implement compared to subjects more dependent on natural language, in terms of assignment generation and automatic grading. The implemented prototype was made with web technologies to make it usable across multiple devices and operation systems.

5.1 Technologies Used

HTML5 canvas and CreateJs was used to make the assignment formats. CreateJs is a set of libraries to make drawing and manipulation of graphics, loading of assets, and play sound in the browser easier. This library was mainly used to create the assignment formats.

Mathjs and MathJax Mathjs was used to generate latex from mathematical expressions. The latex was then rendered to SVG by MathJax.

Neo4j is a graph database used to store the users interaction with the prototype.

Google SignIn is used to identify users, to avoid making dedicated login functionality.

ExpressJs is used to make the REST API for the application, which is responsible for all communication between frontend and backend.

Nginx is the web-server used to serve the the application, and as a reverse proxy for other backend services.

InkScape is a vector drawing software, and it was used for drawing and editing unique components for the prototype.

MarvelApp is a wireframing tool and was used to create the detailed wireframes that is the clickable prototype consists of.

InVision is a digital product design platform, which was used to create the clickable prototype of the wireframes.

5.2 Prototype Design

5.2.1 Gamification & Pedagogical Elements

Points & Achievements

These are most used gamification elements, both in literature and industry. The learner get points for completing tasks. The points are not necessarily useful on their own, but can tie several different gamification elements together. How these points are calculated are discussed below. Achievements are awarded for completing milestones, either by the tasks or by doing activities in the system itself 5.1.

Adaptive Learning

The adaptive learning system in the prototype is largely inspired by the "stock market" in [43]. The reason for this is that it is simple to understand, and simple to implement, yet effective. This approach inflates the value of tasks learners for various reasons negate to do. Making tasks learners do not want to do more attractive.

$$Value(\mathbf{x})_i = \begin{cases} 100, & \text{if } \mathbf{x}_i <= avg(\mathbf{x}) \\ \frac{100 * avg(\mathbf{x})}{\mathbf{x}_i}, & \text{if } \mathbf{x}_i > avg(\mathbf{x}) \end{cases}$$

Here $\mathbf{x}$ is a vector of n-dimensions, one for every task available to the learner. Each entry in the vector is an evaluation of how proficient the learner is with the task. Higher values for x means the learner is more proficient in this task. The proficiency of a task determined by the progress tracking calculation, defined in the progress tracking section 5.2.1. If the proficiency in a task is higher than the average, the reward gained by completing the task will be discounted. The reward will be discounted relative to average proficiency. "100" is an arbitrary baseline reward. A problem with this model is that it does not account for the time it takes to complete the task, making a time consuming task less desirable than a shorter task with the same value. Another problem is the progress tracking equation. By failing a task on purpose, the learner can inflate the value of tasks they prefer.

Figure 5.1: A display of the learners achievements.

Another adaptive learning approach in the prototype is in the generator for fraction tasks. There is a set of templates e.g. $\frac{a}{b} + \frac{c}{b}$, are divided into subsets based on difficulty (operator types and expression complexity). The letters represents random variables that are drawn from a predetermined set. By successfully completing a task, the difficulty is incremented. If providing an incorrect answer, the difficulty decreases.

These adaptive learning methods are by no means complex or sophisticated. They do however provide an entry point that is easy to modify or change. They are relatively fast to implement and they do not require any data. This is the beginning of a bootstrapping approach. When the system is in production it will generate data than can be used to make machine learning models. Which in turn can be used to make even better data sets for more complex machine learning models. For example, in the case of the reward calculation, this function can be replaced by a logistic regression model for estimation the probability that the learner will successfully complete a task. Higher the probability for success is the lower the reward.

Loss Aversion

Loss aversion works in the form of *hearts*. The learner will have to get the answer right in the first attempt to maximize points awarded on task completion. The award is reduced by every wrong answer. The calculation of the awarded points is as simple as $Reward = \frac{Points * LivesLeft}{LivesTotal}$, where "points" is the amount of points the task is worth, determined by the adaptive learning system discussed above. LivesTotal is the number of total lives (hearts) as shown in figure 5.5. For every wrong answer a heart will be lost resulting in a reduction of $\frac{1}{3}$ in reward. This approach to loss aversion, although fairly general, is task specific and will not be applicable to all task types. The

loss aversion mechanism is therefore needed to be implemented in the individual task modules. This functionality is primarily to give the learner a second chance, and opportunity to correct mistakes. That is why loss aversion made its way into the prototype, even though it was one of the gamification elements lowest ranked by teachers.

Customization & Purpose

This includes changing profile picture, and spending points to purchase new colors and styles for the user interface. This is only to illustrate a possible entry point for the customization gamification element (figure 5.2). All though points are motivating on their own, letting learners spend the points they collect in the platform, gives the points a higher meaning. It is limited how interesting buying new colors can be, and how many attractive color schemes that can be created. It is important that the learner finds the things it can purchase with the points worth while. It is also important that purchasable objects are reasonably priced relative to the systems distribution of points, and enough things to buy, so that the learner always has something to work towards throughout its usage of the system. This is a mechanism referred to as *money sinks*. A mechanism often found in open-ended games such as MMORPGS. A possible implementation of such a money sink in a system like this, may be a Tamagotchi, a virtual pet. The learner would then have to gather points to keep their pet alive and happy. Although possibly slightly unethical, it may prove as an effective source of motivation.

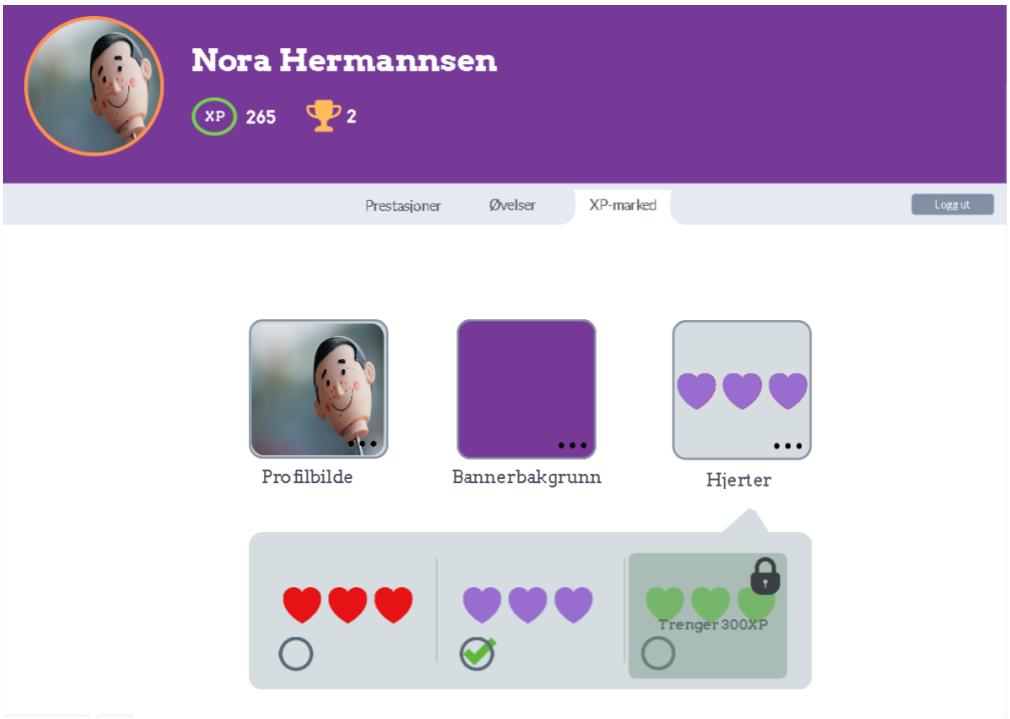


Figure 5.2: A “store” where learners can unlock content by earning points to customize their learning environment. This gives a higher purpose to the points.

Figure 5.3: A representation of the learners skill in the various tasks in the system.

Feedback

The assignments currently implemented are automatically graded. This makes it possible to give the learner immediate feedback through a short animation and short sound clip. Other interactions with the system, like mouse over in the assignments also gives feedback by wiggling. This is to give an impression that the assignments are "alive" an not just static forms.

Progress Tracking

By performing tasks in the system, the learner gets an indication on how well it is currently performing on a task 5.3. This is supposed to represent the learners understanding of the concepts contained in the a task. The learners understanding is calculated by using a sliding weighted average of results.

$$P(\mathbf{x}) = \lambda \left(\sum_{i=0}^{n} \frac{\mathbf{x}_i * \gamma^i}{\sum_{j=0}^{n} \gamma^j} \right)$$

Here $\mathbf{x}$ is an array of task results, where $\mathbf{x}_1$ is the latest task result. An entry in $\mathbf{x}$ is in the prototype 0 or 1, which represents wrong or correct respectively. n is the size of the sliding window i.e. number of results used. γ is the weighting, which gets discounted over time. Recent results contributes more to the score. γ is normalized so that

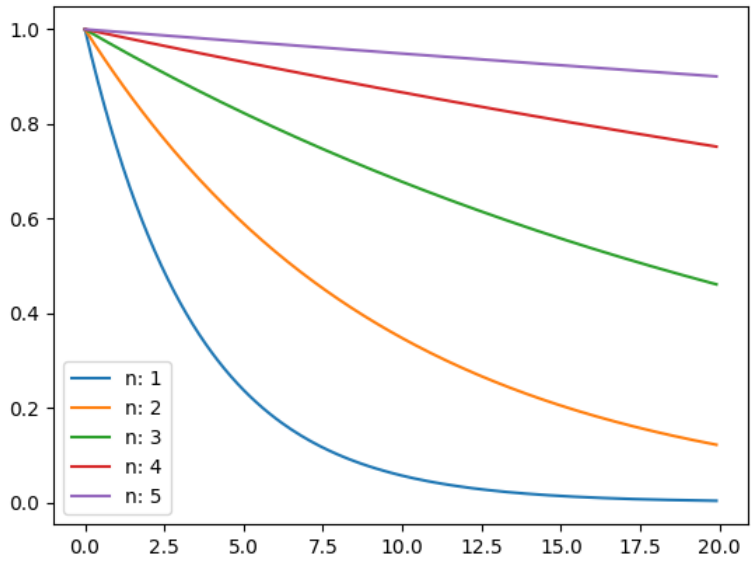


Figure 5.4: A proposed model for spaced repetition. "n" is the number of practise events. X axis represents weeks since last practise event. Y axis is the learners knowledge of the task

$P(\mathbf{x})$ is in the range $[0,1]$. λ is a number in the range $[0,1]$, representing the spaced repetition discount.

$$\lambda = 0.75^{\frac{t}{e^{n-1}}}$$

The spaced repetition function is modelled after the findings in [40]. Here t is weeks since the task was last practised, and n is the number events the given task has been preformed by the students. How many tasks should be completed to count as a new event, and how much time that should pass between tasks for the event counter n to be incremented, is not yet clear. This can be solved by making missions, where the learner must do that specific task a given number of times to complete the mission. This mission could then be made performable once every week, and lucrative in terms of reward . Rohrer et al. [40] uses a week between learning events. They also show that over-learning happens somewhere around three to nine solved problems. This may however vary widely from task to task, and would require further research. This model assumes that retention increases exponentially across repetition events. There is not enough data in Rohrers paper to assume this, but was done to limit total number of repetitions per semester to tree to five.

5.2.2 Application Design

Focused around intuitive design and minimizing number of clicks required to navigate the application. The design principles from Googles Material Design [53] has been used to make the application more intuitive to navigate and to use.

5.2.3 Assignment Design

Final Design

To select a good assignment design, we need to ask what constitutes a good design. Three metrics comes to mind.

- How well does it interact with the learner i.e. does it motivate, does it help the learner attain flow.
- How easy is the design to understand. Can a new user look at the assignments and immediately know what to do.
- How much insight into the learners thought process does the learners interactions with the assignment provide. More insight provides a better foundation to help the learner.

For the sake of the prototype a multiple choice format is used. Though it may not be the most efficient format with respect to interactivity and insight to the learners thought process. Multiple choice is however easy to understand, and it generalizes to most, if not all task types. Another reason for choosing multiple choice that it is extensively tested in educational applications, both digital and on paper. Keep in mind that multiple choice does not necessarily mean the the stereotypical checkbox format. Figure 5.5 shows multiple choice as a set of cards, one question card, and a set of possible answer cards. The learner then clicks an answer card to answer the task. If it is correct the learner is presented with a short "correct" animation. If the answer is wrong a "wrong" animation is displayed. If the learner answers incorrectly, depending on the assignments configuration, the learner will get multiple tries to complete the task. When the final attempt is used the learner will be presented the correct answer, and a short explanation. To assist the learner in the in a problem solving task, a set of embedded YouTube videos, relevant to that task is provided. The learner can also unlock hints by forfeiting the reward (only implemented for dot product). The assignments are made so they can be rendered to any canvas, and gives a callback when the task is finished. Letting the system that called the assignment know that it is finished, and the result of the task. This makes it modular, and ensures that it can be run anywhere there is a canvas to render to. The assignment also saves the state of the current task. This lets the learner exit the task and continue later, for time consuming task. If the task is not saved, the learners can refresh the task until an easy one appears.
Three tasks types that were implemented for this format:

- **Pythagorean Theorem**, the objective of this task is to find the length of an unknown side of a right sided triangle, using the Pythagorean theorem. The difficulty determines which side is unknown, where the easiest task has the hypotenuse as unknown. The wrong answers are generated by drawing random numbers uniformly from $\{x \in \mathbb{R} | 0.66y \leq x \leq 1.33y\}$ where y is the correct answer. If a the same number is drawn twice it is redrawn.
- In the **dot product** task, the learner is to carry out vector vector, matrix vector or matrix matrix multiplication. First the shape of the matrices or vectors are randomly generated, then filled with random integers. The wrong answers are drawn from a hard coded set, but can with some work be generated by frequently used erroneous ways to calculate dot product.

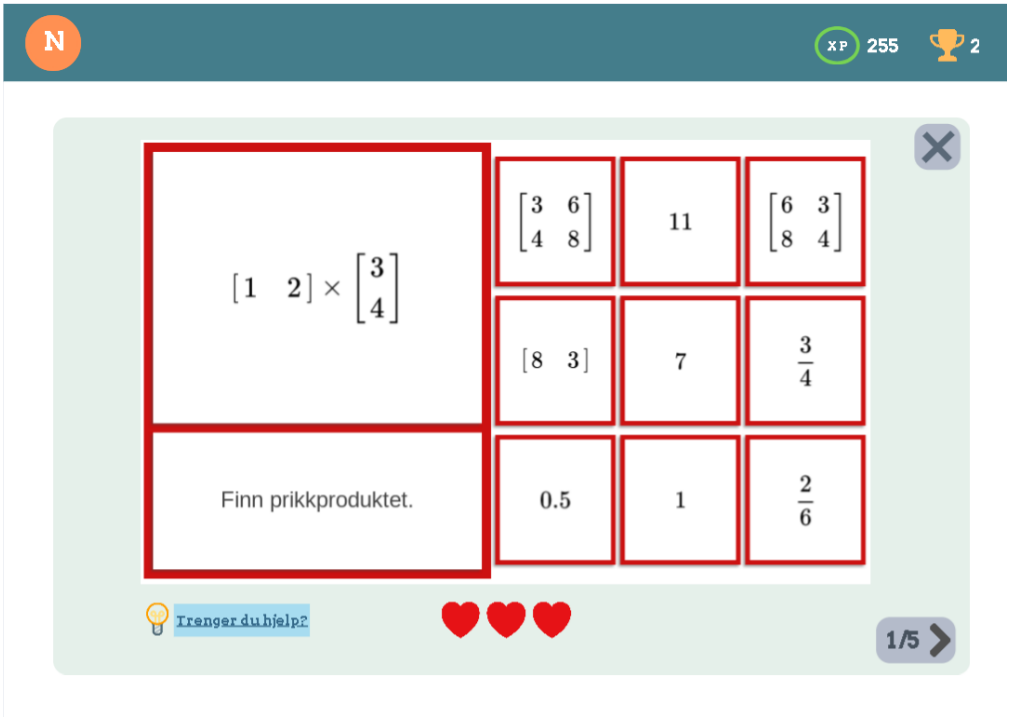


Figure 5.5: A dot product task in the card assignment format

- **Fractions**, is a task where the learner is to either simplify a fraction of carry out a mathematical operations on multiple fractions, with or without a common denominator. The answer may be given in decimal or fraction depending on the task generated. The task fraction is generated from templates mentioned in the section about adaptive learning. The wrong answers are randomly generated fractions, integers and decimal numbers.

Initial Design

The initial design for the assignment format was a card match up game. The point of the assignment is to match up cards that belong together. In figure 5.6 the task is to select a mathematical expression and pair it with its corresponding graph. Tasks for paring graphs to coordinate tables, and paring fractions and percentages.

Concept Sorter (not implemented)

The purpose of this assignment format is to drag objects onto one of multiple classes. By clicking the objects, an info box will appear with information abut the object. Helping the learner make an informed decision about what category the object belongs to. Tasks like the in figure 5.7 can easily be made by learners, give a simple editing tool. This makes this a suitable facilitator of team reciprocal learning technique, where teams can go together to create concept sorting tasks for the other learners.

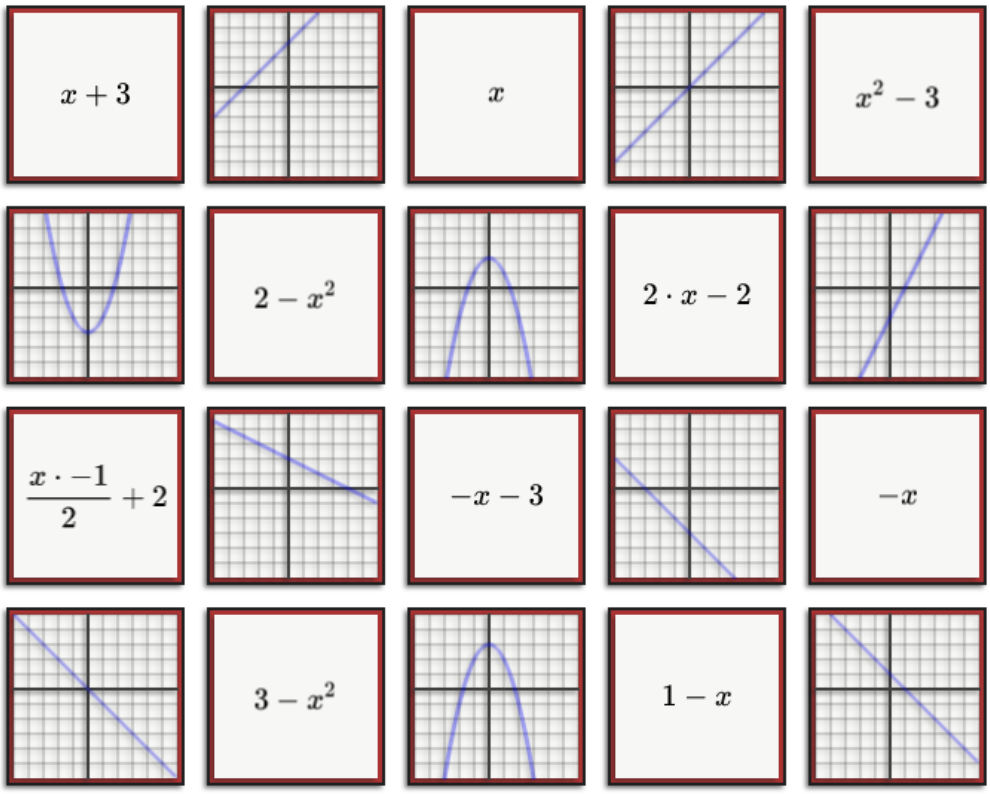


Figure 5.6: The first version of the assignment format. The learner is to pair cards that belong together.

5.2.4 From Idea to Clickable Prototype

The prototype has gone through several stages to get to where it is now. The initial process started with finding out what kind of assignment it should be, and how it would work and what it should look like. Through a creative process inspired by Google Design Sprints method Crazy 8 [54], the result looked a little like a memory game. Where the cards faced the right way up and the game was to find the cards that belonged together. See Figure 5.8. In the end, the assignment was changed to have one larger question card and nine answer cards to choose from. The decision to do this was based on the fact that the traditional memory games often are associated with time constraint or doing it as fast as possible. Considering the complexity of the math, the feeling was that adding a time element would be unfruitful, as it is more important to spend time understanding the problem than solving it quickly. For honing the multiplication table time constraint could be more useful. Another reason for adapting the format was to clarify and focus the assignment to one task rather than many at once. Moreover, another criterion for the assignment format was

Figure 5.8: Illustrating the original assignment idea for the prototype

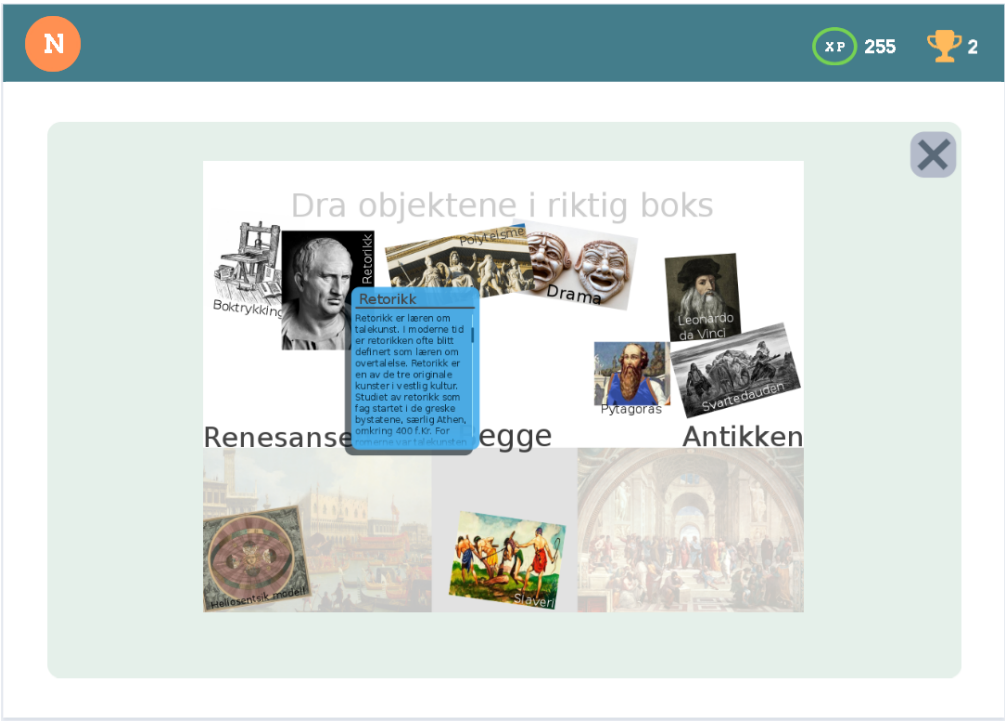
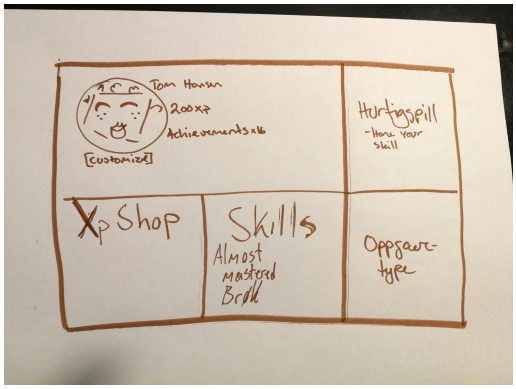


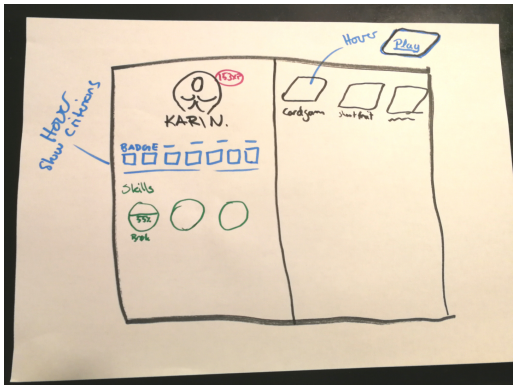
Figure 5.7: Concept sorting, a proposed assignment format

that it needed to integrate well with gamification.

A handful gamification elements, as described above, were selected to feature in the prototype based on findings in literature, existing gamified learning systems and insights gathered from teachers. In the figures below, Figure 5.9b and 5.9a, a couple of the first drafts are shown.



(a) Preliminary draft showing points, achievements, skills, and customization through a profile and xp-shop.



(b) Preliminary draft inspired by single page websites to keep the number of clicks to a minimum.

The process towards the clickable prototype is made up of many sketches on whiteboard and on paper, such as the figures above, as well as sketches of separate components. The final sketches that became part of the clickable prototype are a mix of several sketches voted in, in the fashion of Googles Design Sprints method dot vote [55]. In short, dot voting is a method for making democratic decisions in a team. Every sketch made is presented for

everyone and is voted on by all team members. Each team member gets three voting stickers which they can place on a whole sketch or components in a sketch.

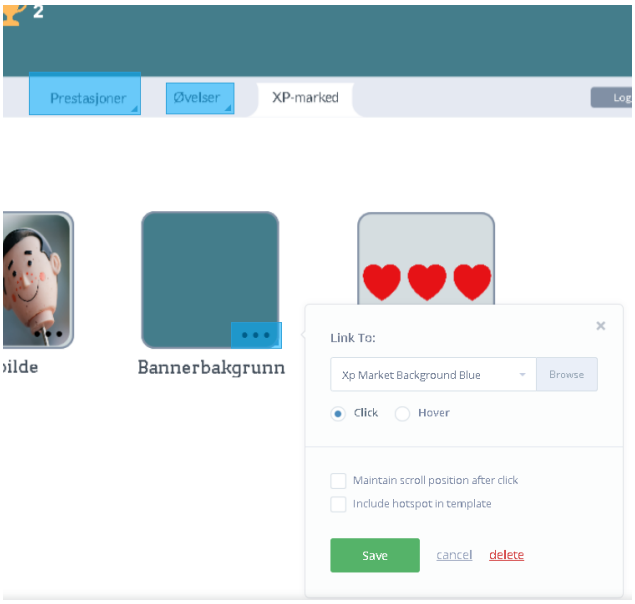


Figure 5.10: Excerpt from inVision - creating clickable components.

Simple sketches became wireframes in the online wireframing tool MarvelApp. At this point details and kinks were tweaked regarding things like colors, icons and sizes. For every action that needed to be interactive and have a response, there needed to be a separate wireframe. To create the illusion that the prototype is functioning like a website, each wireframe was linked using inVision. Marking the area in which should be clickable and adding a link to the next wireframe. See figure 5.10

Chapter 6

Exploring the prototype

6.1 Approach

Moderated usability testing was chosen as the type of testing most suitable for the prototype. Moderated being that the participants are observed live while exploring and performing tasks in the prototype. As the prototype has limited interactivity, it calls for a closer conversation with the participants than if it was a fully fledged system [56]. Moderated usability testing can produce both quantitative and qualitative data, depending on the equipment used. The tests conducted in connection with this thesis were strictly producing qualitative data. It required no other equipment than the device the prototype was tested on, which was a laptop. Another benefit with moderated usability testing, is that it allows for a first-hand account of the participants actions, reactions and body language in relation to gamification as well as the general design [57]. It's an opportunity to impromptu ask questions to the participants while they are on the journey through the prototype. Participants may also ask questions to the moderator either for help or further guidance.
The intention of testing like this was to observe first hand, the participants responses to the gamification elements. To get an indication of how usage of the gamification elements are perceived and test the prognoses from the data collected. Included in this prototype are the gamification elements: points, progress tracking, achievements, feedback, loss aversion and customization. Even a hint of adaptive learning.

Testing with a clickable prototype has its drawbacks. Such a prototype may look more finished and functional than it is, and can therefore induce unwanted frustration in the participants. Managing the participants expectations of the prototype's state is vital in reducing such frustrations. Which is easily done by a good introduction before the usability test begin. A guide for the moderator in the usability test scenario was formulated. With the objective being to help the moderator facilitate the test in such a way that the users would be able to understand the situation and the tasks asked of them. Additionally the guide would assist the moderator in going through all tasks and questions with the participants.

The testing process started out by introducing the usability test, its purpose, what it entailed for the participants, and what equipment was going to be used. At the beginning, and when necessary, the moderator encouraged the participants to think out loud while testing. Then the moderator would described the topic, and moved on to a couple of preliminary questions to get a feel for the experience the participants had on using digital technology in a learning context. See Appendix A.1 for full test plan. Six tasks of various length then followed. The tasks covered the prototypes design and gamification elements. The first task was by far the most extensive and rigid.

1. *Do one assignment in* Matriser/Brøkspill. *First answer incorrectly, get help, then find correct answer.* (T1)
2. *What are you best at?* (T2)
3. *Do you have any achievements? Which?* (T3)
4. *How many points do you have?* (T4)
5. *Change your profile environment to have purple hearts when you play* (T5)
6. *Change your profile environment to have a purple banner in stead of blue* (T6)

Ideally the participants would have been children in secondary school. The original plan was to ask IT-students to participate. Instead students from an assortment of non-technological studies participated. They were in the age range 20-25 and with similar mathematical background.A combination of time constraint, ease of recruitment and the new GDPR rules lead to these participants.

The prototype used in the usability tests can be accessed on Invision via this link: https://invis.io/4NSARTDRS8Y.

6.2 Usability Test Results and Reflections

Three usability tests were conducted. For the first two tests the prototype looked the same, for the third test a couple of tweaks were done to the prototype. A couple of icons were added to the performance tab in an attempt to clarify where the achievements could be found. And the assignment was changed from matrix multiplication to adding fractions to suit the mathematical level of the participant. Table 6.1 shows an overview over each participants success rate in completing the six tasks. The color green implies the participant did the task without friction. And orange implies the participant could not do the task without confusion, missteps or frustration. This is subjectively measured rather than through quantitative methods.

Summarizing the usability test results

	Participant 1 (P1)	Participant 2 (P2)	Participant 3 (P3)
T1			
T2			
T3			
T4			
T5			
T6			

Table 6.1: Table overview of the usability test results for each participant.

Firstly, all three participants had experience with using digital tools in an educational context, mostly from Learning Management Systems such as ItsLearning. Both P2 and P3 remembers playing digital games in primary school and using digital textbooks in a couple of subjects at a later age. The three participants preferred their reading material on paper, and one even preferred doing assignments the traditional way, with pen and paper.

T1 - Doing the Assignment

Each of the participants encountered trouble while executing T1, see table 6.1. Finding and starting the assignment seemed to cause no issue. The were some confusion towards what the points placed on the different assignments in the assignment tab meant. If it was indicative of difficulty level, workload or total amount of points one could earn. The first reaction when starting the assignment from both participants, P1 and P2, who dealt with matrix multiplication was shock and panic. They had never heard or seen this branch of mathematics before. From the beginning they had been made aware that the mathematical problem was tailored to IT-students and that there was no expectation that the participants had to solve it. P1 was the easiest to reassure. P2 on the other hand seemed to want nothing else than to get away from the mathematical problem, and clicked frantically on the screen. P3, on the other hand, who was presented with a fundamental fraction problem was welcoming the task and showed signs of confidence towards solving the fraction problem.

There was some uncertainty regarding the content of help pop-up in the assignment, they questioned its helpfulness. This was directed at the hints that could be unveiled step by step. Here Google was mentioned by two of the participants as the tool they would have sought out to get help in such a scenario. They were more positive towards the video placed next to the hints in the help pop-up.

Receiving points were appreciated by all participants. And the pop-up telling them that they had earned points were noticed immediately after giving the correct answer. Then again, P2 and P3 completely missed the pop-up saying that the answer they had given was incorrect. P1 noticed and was pleased with how the negative feedback

was handled. Liked the supportive tone. With all participants, the reaction to losing a heart lead to an immediate attentiveness and surprise. There was an uncertainty if the three hearts in the assignment meant three lives for each math problem or for the assignment as a whole. They showed signs of timidness to continue before it was confirmed that it was three lives per math problem.

Reflection

In hindsight this task should have been divided into smaller tasks to make it easier for the participants to follow. This task revealed the difference the difficulty level has on learners. The reaction of shock and panic when met with a mathematical problem that is unfamiliar. As opposed to the confidence exuded at one that seems manageable. This goes to show how important it is to consider the knowledge level the learners are at when assigned tasks. Adaptive learning seems a suitable tool to help solve this issue. Unfortunately it is difficult to simulate in a fairly simple clickable prototype.

It is stiff competition with Google when it comes to help with schoolwork. The issue with the hints in the prototype seemed to be that there was not enough information available. Videos do tend to convey more information in a shorter time. It could be that videos are a more common way for learners to take in information. Both Khan Academy and Campus Inkrement use videos to communicate learning material. One could consider focusing on having video lessons readily available along side the assignments, and not as hidden hints. This way the learner can apply knowledge immediately. Or another approach could be to start an assignment with having a brief and voluntary lessons on what's to come, and have these lessons at hand throughout.

Why the pop-up about the answer being incorrect was ignored and not the one with good news is not clear. A guess would be that it is not as interesting to get bad news as it is being awarded points. It could also be that highlighting the incorrect answer in grey was enough feedback to nudge the participants to try again or seek help. It was mentioned that the size of the pop-up was good because it didn't feel like a disturbance.

Loss aversion was one of the gamification elements the teachers were negative towards see chapter 3.2. The timidness displayed towards continuing the math problem in the participants may be what the teachers had experienced with such negative feedback. It did, however, alert the participants and it seemed like they felt like they had something to loose. It could be that this is pertinent in some cases; for testing purposes and less so when practicing new skills. To clarify the points a solution could be to add a plus sign in front of the number.

T2 & T3 - The Learners Skills and Achievements

Mostly, locating the information about their performance wasn't an issue. Nonetheless, first instinct for P2 was to look at the assignments to find out what skill had the highest mastery level. Understanding the skill measures in

the performance tab was no trouble for the participants. P3 would prefer to have the assignment tab as the first page rather than the performance tab which is the case at the moment. Reasoning that it is the assignments which are the main event of the system.

With the achievements there were some confusion with language for P1 especially. P1 could not connect the Norwegian word for achievements with the English word. This lead to difficulty locating the achievements. Yet, both P2 and P3 found the achievements effortlessly. The problem for P3 was distinguishing which achievements were obtained.

Reflection

It is a valid point having the assignments as the first thing the learners are met with. The idea behind having the performance tab as the starting point, was making the learners aware of how they are doing so they could make an informed decision on where to go next. Making the assignments the starting point, could contribute to lessening the burden for the weaker learners who might feel the system confirms their ineptitude. It is worth taking into account in later work.

The English word for the gamification element achievements seems to be more known than the Norwegian translation for it. It could be that even for a Norwegian system that some terminology must remain English because they are too well established, even for younger children. This could be the case for words like achievements, badges, XP and streak which have a strong links to games and applications on any device today.

Giving achievements which are obtained brighter colors and others grey tones is a good solution to make them distinct from each other.

T4- XP: The Learners Earnings

Looking at table 6.1, T4 is one of two tasks all the participants succeeded in. Equally for all, there was no hesitation when asked how many points they had earned in total.

Reflection

The lack of hesitation may indicate the importance put on the points by the participants, and also the familiarity with the gamification element.

T5 & T6 - Customizing the Environment using Earnings

These tasks created the most enthusiasm among the participants. Both P1 and P3 had many ideas as to what could be unlocked with points. E.g. unlock play time for particularly fun games or unlock more educational games. And P1 was quite upset by the fact that changing the profile picture wasn't an option at the time. P1 said that the

picture wasn't representative. Seen from the overview table 6.1, the previously mentioned participants had some trouble with T5. This was on account of not quite knowing where to look to complete the task. P1 expected it to be connected to the profile picture and clicked on that. And P3 couldn't quite make sense of "XP-marked" as a concept at first, but figured it would be the place to go on account of the elimination method.

Reflection

It might have been unnecessary to have these tasks separate. Table 6.1 does however show that the participants learned from one task to the other. A simple title change could remove the friction that occurred in not finding where to make changes to the environment in the prototype. It could be that "Settings" or "Edit environment" would be better. Another suggestion could be to have a dedicated profile page instead of the tab "XP-marked", and have it be part of that.

The enthusiasm the participants showed about using the points to “buy” simple things like new colors or images substantiate both the gamification elements customization and purpose. Giving the points another meaning seemed to be effective in sparking joy in the participants. Also, the upset P1 felt about the state of the profile picture could be interpreted as an attempt to claim the system and extend some personality to it.

Chapter 7

Discussion

7.1 State of the Art

For the commercial "next generation learning systems". It seems that they all have one thing that they do well. Kikora has the assignment format with best feedback, but has no instruction on how to solve the assignments. Khan academy is best on instructional videos, and the assignments are adequate, and has by far the best implemented gamification elements. Campus Increment is a less developed Norwegian Khan academy clone, but the material it provides is a supplement for the textbook used in many Norwegian primary schools. The commercial platforms cover primary and secondary school unlike the systems created for academic case studies. These systems are only directed towards higher learning. This is understandable, as college students are readily available to researchers, it does leaves a gap in the literature. There is not much research on how digital learning systems affect younger learners, how they are perceived, and how they are used by learners in primary and secondary school.

7.1.1 Assignment Formats

Multiple choice is currently the most common assignment format used today. It is used by both commercial and non-commercial learning software. This is nothing if not a testament to how underdeveloped digital learning systems are. According to the literature on active learning strategies, the assignments should be front and center in the learning process. The assignments are where deep conceptual understanding is formed. Instead the assignments are used as a confirmation tool to see if the learner has understood the material during another part of the learning system. A problem with multiple choice is that the learner is given the answer with the problem. In some cases this lets the learner infer the correct answer from the set of answers without ever doing the task. Another problem is that the teacher has no insight into how and why the learner chose a particular answer. For a wrong answer, did the learner simply click the wrong answer by mistake? Did the learner make a partial mistake in the solving the task, or has the learner failed to understand the entire concept? The best format encountered is without a doubt Kikoras. This was the only format that gave feedback throughout the problem solving task, and not just right or wrong for

the final answer.

When it comes to digital assignment formats that seeks to facilitate for and to improve under utilized pedagogical approaches, it seems to be a gap in the market. Literature and educational platform providers praise how new educational technologies has made flipped classroom possible. Still, it does not seem to be any efforts to do the same with other pedagogical techniques.

7.2 Lessons Through Development

To quote Richard Feynman "What I cannot create, I do not understand". Although implementation of the prototype was time consuming, like programming often is, encountering minor problems and bugs along the way, it was not insurmountable. Given a little more time and a small team of specialists in pedagogy, design and user experience, it would not be unrealistic to achieve a product capable of competing in the current industry. The most notable problems were in development of the assignment format. The initial brainstorming sessions resulted in a card game, where the learner is to pair the matching cards (see section 5.2.3). This crowded the screen and limited room for instruction and task complexity. This resulted in the transition towards the multiple choice format. This was unfortunate, as we tried to break from the multiple choice trend. Still, the format is, or has the potential to be more stimulating than radio buttons.

7.3 Digital Advantage

It is hard to say if a gamification element is good or bad. In the process of optimizing the learners motivation, it is fair to assume that the No Free Lunch Theorem applies. If it does, it means that the benefits of all gamification elements are equal if averaged over all contexts and learners. Even if the benefits of gamification proves to be marginal, the advantages of adapting textbook and textbook assignments to a digital format can still be plentiful.

7.3.1 A Learners Perspective

Through gamification we try to motivate learners to not only learn more now, but to internalize this motivation to keep learning later when the extrinsic motivators are no longer present.
Digitalization has the power to give more autonomy to the learners. The learner can choose its own path through the curriculum, and be presented with the material in a semi structured way, without the explicit teacher interaction. By avoiding overlearning, the learners may learn more in the same time span. This may open up to the possibility of learners taking individual paths throughout their respective education. Which in turn means that each learner at any given time is in a different educational state, i.e. one learner has knowledge another learner does not yet have. It would be interesting to see if this knowledge inequality would lead to automatic reciprocal learning among students, a trading of knowledge.

A learner in the Norwegian school system, like many other countries, has to choose between a rage of upper secondary school courses (vocational and tertiary education), at the end of secondary school. When most of your life experience is from a classroom, it is not a small task to decide what you want to do for the rest of your life. Maybe you do not know what choices you have, or what these choices entail down the line. The aggregated data from student interaction in an educational system may be used to create a recommendation system to suggest what you could do after secondary school. Although the primary benefactor of such a system are the learners, it may help save money and resources by reducing dropout rates, and by reducing the need for re-schooling by predicting the future job market.

7.3.2 A Teachers Perspective

The data generated by learner interaction will be valuable for further iterative improvements, especially in the use of AI to make new assignment formats possible, and assist in existing ones. Having access to this data may also free teachers from time consuming tasks like grading, and still allow them the freedom to execute the nuances grading requires. Their time can be better spent on other tasks. A business intelligence equivalent to the classroom can give teachers better insight into the progression of the students, catching when and where students are falling behind.

Learning is not limited to learners. Like many other fields, pedagogy too progresses after pedagogy students graduate. Through the support of pedagogically sound learning tools, teachers can try out pedagogical strategies they are not completely familiar with. By reducing the cost of failing, a digital system acts as scaffolding for continuously developing teachers, helping them stay up to date.

7.3.3 A Research Perspective

The research available on learning systems are mostly for higher education. And may not be applicable to the public school in Norway. It is also possible that the research of digital learning systems are biased because of student excitement due to novelty. Another problem with current research is that a complete system is created from scratch and evaluated as a whole. This makes it hard to evaluate individual components contribution to learning. It is also hard to evaluate these adhoc systems relative to traditional educational practises, as they are experimental, usually created by professors, and therefore highly inferior in quality to a commercial system. An unappealing or partially implemented system may negatively affect the students motivation and diminish the systems efficiency. In comparative studies between digital learning systems and traditional education, this reduced efficiency may act as a bias against the digital system.

A highly modular system opens up for the possibility to test components on a random sample of the user base without any interruptions in the learning process. To conduct a similar study today, one would have to physically conduct pre- and post tests on both groups which would be intrusive to the classes. All data would have to be

recorded manually. A well designed system could generate anonymous data sets from every single learner, which could be a massive contribution to pedagogical and didactic sciences.

7.3.4 A Commercial Perspective

In 2006 every secondary school learner in Norway was given a personal laptop for school purposes. Two years after, the Android operative system was used for the first time on a smartphone. If one were to compare advances in software between the two, from their inception till now, software for secondary school education would appear almost stationary. A lot of androids success can be attributed to good UX (user experience), the Appstore and a well documented and designed API (application programmable interface). Well thought out and iteratively improved UX is important, it makes it easier for new users to use the product. It also makes the product seem more organic, and less like a chore. The Appstore helps content creators publish their work, and makes it easy for consumers to find, install and review products. This helps other consumers evaluate a product before buying and gives valuable feedback to content creators. A good API and developer tools, allows a developer to focus on core ideas of an application and lets the API handle generic parts frequently used. This not only helps the developer get the product in production faster, but also streamlines user interaction by having similarities across applications.

7.4 Cautions

Students are different to one another. They have different goals and interests, and are motivated by different things. This is reflected by the literature and the interviews and questionnaire conducted in this thesis. It is important to keep in mind that mechanisms that help motivate some, may be harmful to the motivation of others. This is most thinkable to appear in mechanisms of direct competition, or where the mechanisms can be used to rank the involved learners. For the lower performing learners, these mechanisms may be perceived as loss in self worth and social status. This may cause students to be reluctant to participate in academic endeavors, or even withdraw entirely. One should therefore be vigilant when applying gamification elements in a pedagogical context.

Implementing gamification elements is not a straight forward task, this is especially true for elements where learners are rewarded. Making sure that the right behavior is reinforced can be complex. This was noted by [44] when most of the reward was given to the learners early on in the course, leaving little incentive to use the learning system towards the end. In the worst cases where the implementation of gamification elements are poorly executed, it can lead to the system being exploited by the learners.

Chapter 8

Conclusions

8.1 Summary

In section 2.3 gamification elements eligible in an educational context have been described. These gamification elements have then been substantiated by theory in the fields of psychology and pedagogy. The section on pedagogy 2.4 also defines pedagogical approaches without ties to gamification, that can benefit from digitalization. As a supplement to determining which of these elements are best suited for learning, the opinion of teachers and pedagogical professionals was sought. On the background of the information uncovered, a prototype was developed. The prototype demonstrates how some of these elements can be implemented. Chapter 4 looks at the state of the art of digital learning systems in academia and industry. It was discovered that most if not all academical studies of learning systems concerning gamification and pedagogy, are conducted on college students. This is unfortunate as gamification elements and pedagogical techniques may not have the same effect on children of all ages, as they do on adults. The quality of the systems used to test gamification elements were poorer than the students may have been accustomed to. And as such, the evaluations may have been colored by the students expectations of functionality and design. Digital learning systems provided by the industry covers the entire duration of public school. These systems still have a long way to go as each of them focus on a small subset of motivational and pedagogical techniques and little innovation when it comes to assignment formats. Lastly we discuss the effects further work and improvements may have on education.

8.2 Meandering - The Road to the Finished Thesis

The initial goal of this thesis was to find and asses gamification elements, as a means to improve education. This information was then to be used to implement a high-functioning prototype for testing effects of different gamification elements on children in secondary school. This plan was abandoned when realizing the difficulty of acquiring children under 18 years of age for testing purposes. And several iterations of planning and design processes in the early stages of the thesis made it clear that it was unrealistic to undertake the set course. Assessment of assignment

formats and further exploration of pedagogical techniques realizable by technology, had by then been encountered by the authors as an interesting direction, and was chosen to take the place of comparative testing.

8.3 Findings

Through extensive research and consultations with teachers in various ways the following conclusions were drawn:

- **What gamification elements exist in current literature and industry? (RQ1)**
  What became clear early on was that there exists a vast number of gamification elements. A selection of gamification elements were presented in this thesis, presented on the basis of popularity/familiarity or relevance to pedagogy. A literature review of research on experimental gamified learning systems were conducted, and revealed a handful gamification elements which had been put to the test in a realistic environment. Several gamification elements were overlapping in the studies, among them the classic **reward system**, consisting of a type of points, and accompanied by **leaderboards**. In addition to these gamification elements Ibáñez et.al and Barata et.al included **badges**. Moreover, the gamified learning systems practiced **rapid feedback cycle** on the student's interactions with the systems, plus in Ibáñez et.al peer reviewing was a significant technique utilized to provide learners feedback on their performance. Ibáñez et.al also introduces a form of dynamic difficulty to guide the students towards a broader learning horizon, which has a strong affinity with **adaptive learning**. Again, the studies are similar in that the gamified learning systems have a specific **purpose** for their use. Lastly, the gamification element that is always implicit, if elements such as points and leaderboards are present, is **competition**. The studies have differing degrees of competition, however all have the learners competing against each other.

  In addition to the previous elements the industry presents a number of other gamification elements. Customization is one of them; implemented as an editable profile for the learners. E.g. avatar, public nickname, the avatars background. Next gamification element is sound, which were found as sound effects in relation to the learners interactions and background music/sounds that aren't affected by the learners interactions. Moreover, Easter eggs were found in the form of badges with secret conditions. Most of the digital learning systems in this thesis made use of themes. Either in individual tasks or as a theme throughout the digital learning system. A couple of other elements that were found in all of the digital learning systems were quests and progress trackers.

- **Which of these gamification elements are viable candidates for use in the Norwegian school system? (RQ2)**
  The data collected from teachers, in the form of a survey and interviews, goes towards answering this question. Along with the research gathered in this thesis. It must be made clear that the candidates considered viable, are merely indications on whether they will give positive results, as thorough testing in accurate envi-

ronment is needed to conclude with certainty.

The classic gamification elements, Points, Badges and Leaderboards, were found in current literature as shown above. Looking at the data from the survey there are an overall positivity about having a reward system as a motivational tool. In the survey badges were regarded in a favourable light, yet a little less so than a reward system like points. The interviewees in 3.1 said to experience points as a motivational tool as very positive for their learners. The same was also observed in the usability tests. Last of the classics in PBL is the leaderboard, this gamification element was not as well thought of as a motivational tool. The teachers opinion of leaderboards in the survey were on the negative side of the scale. Concerns were raised about leaderboards having a harmful effect on the more disadvantaged learners. Increasing the gap between high performing learners and poor performing learners.

This naturally brings up the gamification element of competition. Competition was discovered to be an element in which teachers were rather ambivalent with respect to learners differing motivational types and level of knowledge. Team-based competition was marginally better received as a motivational tool than individual competition. Even considering the ambivalence, the survey showed a positive average on both styles of competition. There were relatively few participants who took part in the survey and so outliers may have a dramatic impact, and what may be considered trends could be a coincidence. Therefore it is difficult to draw a conclusion with confidence.

The survey identified adaptive learning as a good contribution to a digital learning system, this is supported by the usability tests. There was a clear difference in motivation in the participants who were presented with a task too difficult and the participant who had a more suited task.

In short, reward systems, badges, adaptive learning and feedback on behaviour and progress are viable candidates for the public school. On the other hand, leaderboards and competition elements are not as suitable, but not unacceptable in well thought out scenarios or as optional elements.

- **What kind of digital education assignment formats exists today in gamified learning systems? (RQ3)**
  Looking at the selection of digital learning systems there is one digital assignment format that stands out; multiple choice. This particular format is not unique for the digital arena, but frequently used for its simplicity. It was utilized by all of the digital learning systems presented in this thesis. The second most used digital assignment format found was free form text. Free form was used to input either short answers (one or two words), or to write code snippets. The one that used code snippets, was graded using peer review. Graph tool was used to graph mathematical equations. Drag and drop, was used to drag one element onto another correlating element. This type of assignment format were found in some of Salabys assignments.

These assignments were more game-like than other assignment formats encountered. It allowed the learner to interact more with the assignment.

In conclusion, there is room for innovation in regards to broadening the variety in assignment formats. There were in total four assignment formats found: multiple choice, free form text, graphing tool and drag'n'drop. Most often presented in their traditional form.

- **What are the possible effects of utilizing gamification elements and digitized assignments as pedagogical tools in the Norwegian public school system? (RQ4)**
  Throughout the literature, pedagogical strategies show to be better than current pedagogical practises are found. Too few teachers per learner and a high competence level to use efficiently, are some of the reasons why these strategies are not used. Technology has already proven to reduce these requirements for some strategies, all of which has the potential to improve pedagogical quality. Well crafted learning systems may also help teachers keep up to date on current pedagogical techniques, through frameworks and example activities, by reducing risk of trying new things.
  More computer usage in school can generate data, when combined with learning analytics can assist teachers in their practises. This will provide teachers with more insight into their learners development.

8.4 Limitations

- **Research and studies on gamification are predominantly conducted on learners in higher education**
  A discovery we made early, was that most research on the subject of gamification was done in higher education rather than primary school. The consequence is that the research is not within the target group of primary school and secondary school learners, and so it is less than a perfect starting point. Most likely this is the case because it is easier to run studies on adults than children under 18 year of age. With children a higher level of effort when it comes to permission, a parent or guardian has to consent that their child may participate.

- **The survey**
  Firstly, the number of participants in the survey were in the lower range. For this reason we had to precede with caution regarding what looked like correlations or definite results. It might have been a larger pool of participants if the survey had been conducted at an earlier time in the school year. Secondly, we were made aware that there should have been an option to opt out and answer "don't know" or "not relevant" on the statements. A couple of the participants expressed this in the comment section of the survey.

- **The prototype**
  It is between a low-fidelity and high-fidelity prototype, which is not a limitation in itself, however it does mean that the prototype is not highly functional and interactive in every aspect. On the other hand it allows faster

changes and is far less costly and rigid than an implementation or a true high-fidelity prototype. A weakness with the prototype is how few it was tested on, and that it was not tested on the target group. The consequence is that the data collected may not represent the target group accurately. The risks with few users are not discovering the variety that exists in people, both when it comes to user pattern and perspective. Another limitation may be how the usability test was facilitated. The path through the prototype was fairly strict, and so the users were left with fewer exploration options, and as a consequence the tasks were detailed. The reason for this restriction was to take advantage of the fact that this way of prototyping is less time consuming than a fully interactive prototype or an implementation. To get more freedom in the prototype it would have needed more time on the drawing board. It was not a priority, as it was more important to test the elements already in place.

8.5 Recommendations for Further Work

8.5.1 Short-term

The set of models for adaptive learning, progress tracking and spaced learning proposed in this thesis is currently not tested on learners. The models need to may need to be parameterized to better fit different assignments, and different types of learners. It also has a few flaws mentioned in the development chapter; such as intentionally failing an assignment to inflate its reward. This makes it vulnerable to exploitation. A possible solution could be a mechanism that insures that the learner has made a sincere attempt to solve the assignment.

Conduct a study on the relationship between over-learning and motivation. During the literature review no such study was found. It is not unthinkable that over-learning may reduce motivation due to boredom. Over time this may manifest it self as negative associations towards learningThis information may strengthen the ar. gument for usage of adaptive learning strategies.

8.5.2 Medium-term

The findings uncover that existing assignment formats currently used by commercially available learning tools, are in most cases multiple choice, and is in some cases simply implemented as a HTML form of radio buttons. This is uninspiring. It may not be detrimental to learners motivation, but is does little to improve motivation. It is our expert opinion that further exploration and development of other types of assignment formats will be an unavoidable contribution to the future of digital education. More intricate formats has the potential to not only increase learner motivation. They may increase the detail of feedback given to the learner throughout the assignment process. They may change the way the learner perceives or interpret the subject. They may make the learner aware of, emphasise and assist in meta-learning, improving the learners ability to learn in the future. They may demonstrate how the assignment relates to real world applications.

Identify pedagogical techniques and how they can be strengthened, both in efficiency and usability through technology. Create general digital frameworks that can be extended to specific use cases. An example would be one of the cooperative learning strategies mentioned in section 2.4.2. A specific use case could be a reciprocal learning facilitation tool, where the tool selects who is the teacher and who is the learner, picks the topic and provide question suggestions. In this case the tool would reduce the time spent by the learners getting ready to work and reduce the time it would take the teacher to organize the learning event. This work can help teachers organize and use pedagogical strategies previously not feasible due to time required to plan the event, and number of teachers required to execute the event without digital tools. It can also help reduce knowledge and experience required to efficiently use the learning strategy.

8.5.3 Long-term

The development of a system in perpetual beta which constantly changes to facilitate the needs of the involved parties, learners, teachers, scientists, content developers and policymakers, with emphasis on the learners. The educational environment is constantly changing, so it is only natural that such a system needs to be able to change with it.

Create incentive programs for teachers to utilize existing and emerging technologies and pedagogical styles. It would also be beneficial for larger learning institutions to have a support team with the sole propose to assist teachers in adapting and renewing their courses. This type of team could consist of specialists in pedagogy, media production and graphical designers. This could help ease higher institutions away form the familiarity of passive learning, and relieve students from the irony of a teacher professing technology in a way that could be replaced by something as archaic as VHS.

Appendix A

Additional Information

Digitale oppgaver

* Required

Dette er en spørreundersøkelse rettet mot lærere i forbindelse med en masteroppgave i informatikk ved NTNU. Vi ser på hvordan digitaliserte skoleoppgaver kan implementeres for å gi elevene best læringsutbytte, gi lærerene god oversikt over elevenes progresjon, samt spare dem for repetetivt tidkrevende arbeid. Hensikten med spørreundersøkelsen er å kartlegge hvilke virkemidler som best bidrar til økt læringseffektivitet og motivasjon i følge lærere.

Spørreundersøkelsen består av fem deler. Først kommer noen innledende spørsmål, deretter blir du presentert med noen påstander om elevers motivasjon og læringsutbytte. Undersøkelsen avslutter med noen påstander som har et lærerperspektiv. Det hele vil ta ca. 7 -10 minutter. Vi setter stor pris på om du svarer på undersøkelsen innen mandag 4. februar.

Ved spørsmål eller andre henvendelser ta kontakt på epost.
sigridrt@stud.ntnu.no
oakjeser@stud.ntnu.no

Takk for ditt bidrag :)

Hilsen Sigrid Rein Trustrup og Ole-Alexander Kjesrud

Samtykkeerklæring

Ved å gjennomføre denne spørreundersøkelsen samtykker du til at dataene du oppgir, blir brukt i vårt masterprosjekt ved Institutt for datateknologi og informatikk på NTNU. Vi forplikter oss til at all data forblir anonyme i masterprosjektet. Du tillater at dataene du oppgir kan bli lagret i sammenheng med prosjektdokumentsjon til gjeldene masterprosjekt. ved utgangen av 2019 vil fritekst bli slettet.

Om deg

Her lurer vi på litt om deg som lærer og dine holdninger og bruk av IKT i arbeidshverdagen.

1. **Hvilke(t) årstrinn underviser du i?** *
   Check all that apply.

   - [ ] 1. - 3. trinn
   - [ ] 4. - 7. trinn
   - [ ] 8. - 10. trinn
   - [ ] 11. - 13. trinn
   - [ ] Other: _____

2. **Hvor lenge har du jobbet som lærer?** *
   Mark only one oval.

   - ◯ 0 - 3 år
   - ◯ 4 - 10 år
   - ◯ 11 - 19 år
   - ◯ 20 år eller lenger

3. **Hvilke fag underviser du i?** *
Check all that apply.

- [ ] Norsk
- [ ] Engelsk
- [ ] Matte
- [ ] Naturfag
- [ ] Samfunnsfag
- [ ] Språk
- [ ] Historie
- [ ] Other: _____

4. **Hvilke digitale verktøy bruker du i din arbeidshverdag?** *
Check all that apply.

- [ ] Presentasjonsverktøy eks. Powerpoint, Google Slides, Prezi
- [ ] Samskrivingsverktøy eks. Google Dokument
- [ ] Delingverktøy eks. Dropbox, Google Disk
- [ ] Læringsplattform eks. itsLearning, Blackboard, Fronter
- [ ] Digitale lærebøker
- [ ] Google Sites
- [ ] Quizverktøy eks. Kahoot, SurveyMonkey
- [ ] Khan Academy, Brilliant.org eller lignende
- [ ] Digital kommunikasjon eks. Slack, Messenger
- [ ] Ingen
- [ ] Other: _____

5. **Hvor ofte benytter dine elever seg av PC/nettbrett i undervisning?** *
Mark only one oval.

- ◯ Hver dag
- ◯ Noen ganger i uken
- ◯ Noen ganger i måneden
- ◯ Noen ganger i semesteret
- ◯ Aldri
- ◯ Other: _____

6. **Hvor mange elever er det per enhet (PC, nettbrett, ol for skolebruk) i din klasse?** *
Mark only one oval.

	1	2	3	4	5	6	
Én eller flere enheter per elev	◯	◯	◯	◯	◯	◯	6 eller fler elever per enhet

7. **Hvor lett synes du det er å finne gode digitale ressurser til bruk i undervisning?** *
Mark only one oval.

	1	2	3	4	5	6	
Svært vanskelig	◯	◯	◯	◯	◯	◯	Svært lett

8. **I hvilken grad er tilgjengelighet og kvalitet på digitale ressurser en begrensning for din bruk av digitale ressurser i undervisningen?** *
Mark only one oval.

	1	2	3	4	5	6	
I liten grad	◯	◯	◯	◯	◯	◯	I stor grad

Digitale oppgaver

Her ønsker vi å vite hvor enig eller uenig du er i de følgende påstandene om oppgaver, og hvordan det påvirker elevens læringsutbytte og motivasjon.

9. **Å få individuelle oppgaver utifra egen prestasjon øker elevens læringutbytte.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

10. **Å få individuelle oppgaver utifra egen prestasjon øker elevens motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

11. **Å kunne fritt utforske og gjøre oppgaver hvor som helst i pensum, og få uttelling for dette øker elevens læringsutbytte.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

12. **Å kunne fritt utforske og gjøre oppgaver hvor som helst i pensum, og få uttelling for dette øker elevens motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

13. **Å få repetisjonsoppgaver i bestemte intervaller øker elevens læringsutbytte.** *
Mark only one oval.

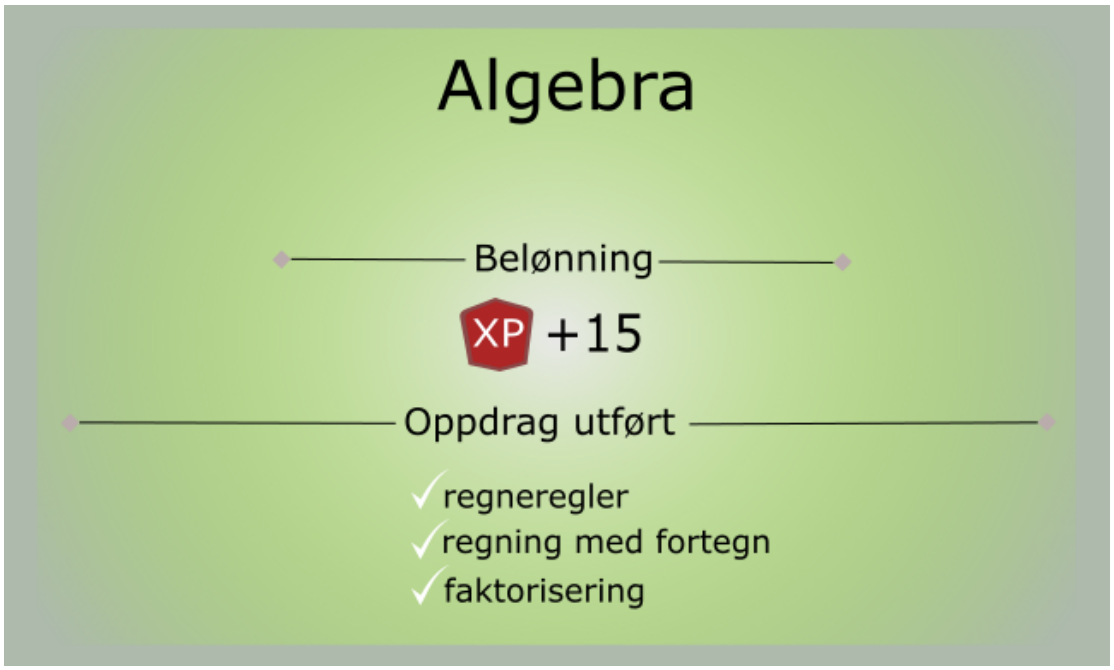
	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

14. **Å få repetisjonsoppgaver i bestemte intervaller øker elevens motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

Tilbakemelding

I denne seksjonen ønsker vi å vite hvor enig du er i påstandene om tilbakemeldinger elever kan få av et digitalt oppgavesystem.



15. **Å få tildelt poeng (XP) for å gjøre oppgaver øker elevens motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

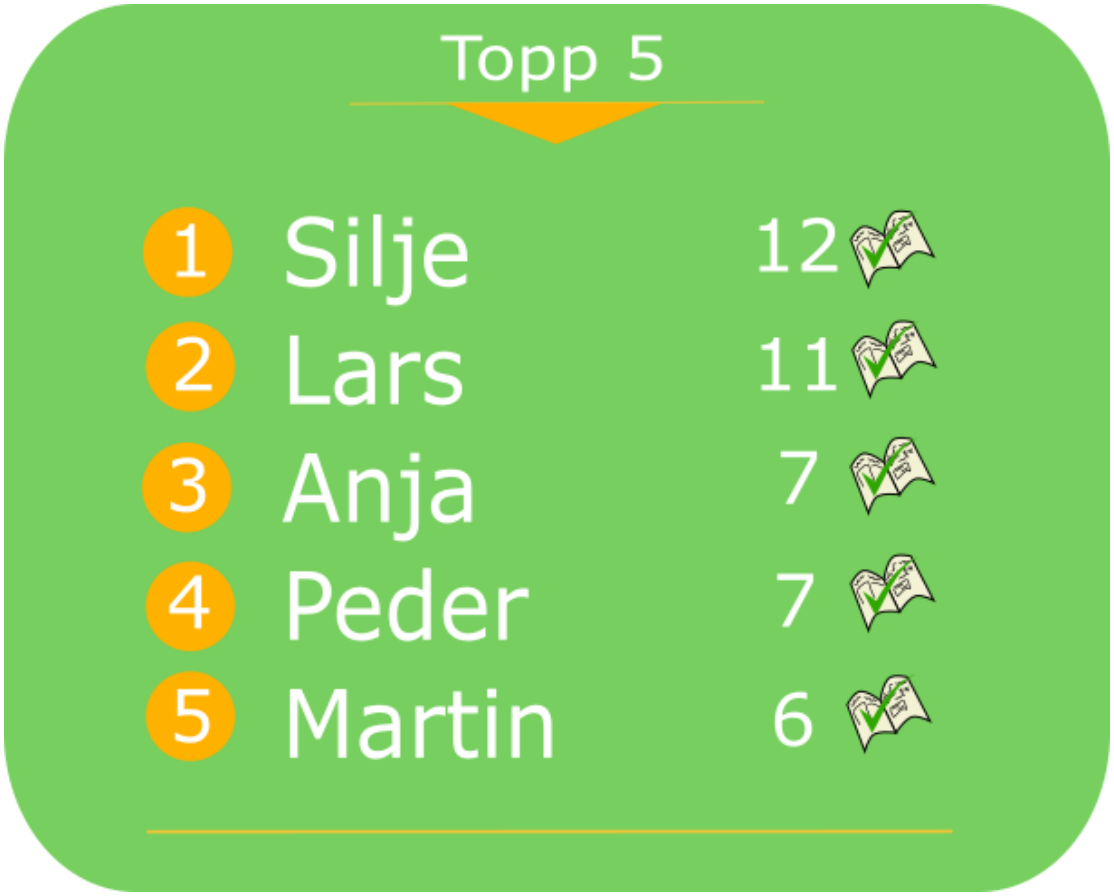
16. **Å miste poeng/progresjon ved lengre opphold fra oppgaver øker elevens motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

17. **Å få tildelt ferdighetsmerker (badges/achievements) ved oppnådde milepæler øker elevens motivasjon.** *

Mark only one oval.

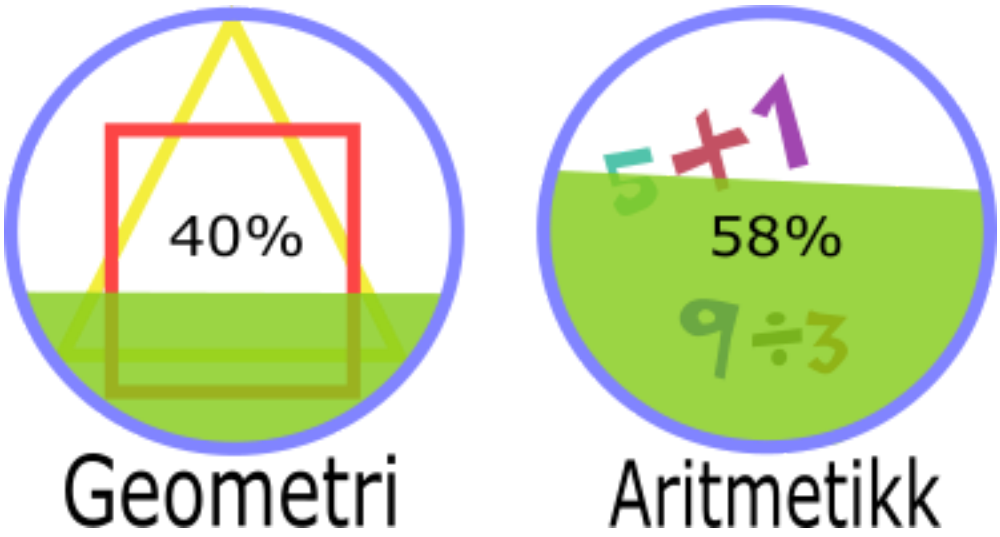
	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig



18. **Å få tavle med toppliste over de som oftest gjør oppgaver øker elevenes motivasjon.** *

Mark only one oval.

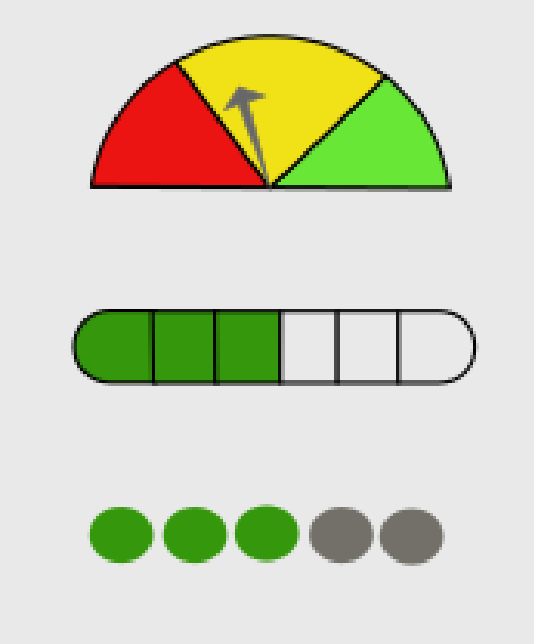
	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig



19. **Å få en grafisk fremstilling av sin beherskelse i deler av pensum øker elevens motivasjon.** *

Mark only one oval.

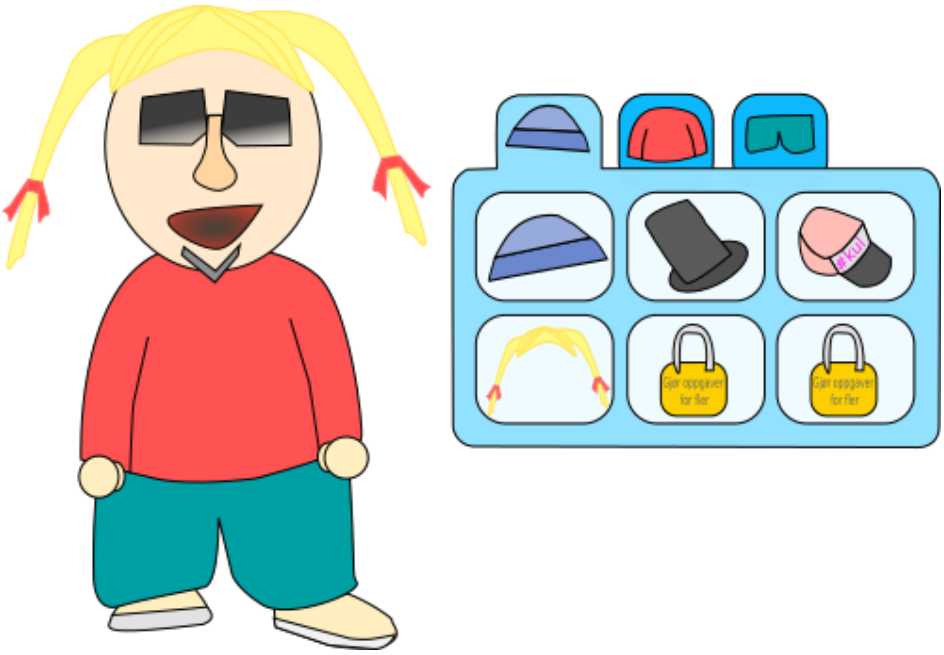
	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig



20. **Å ha visuelle fremdriftsindikatorer på leksene øker elevens motivasjon.** *

Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig



21. **Å få tilpasse sitt digitale læringsmiljø. For eksempel ved å ha en avatar de kan sette sitt preg på øker elevens motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

Sosialt

Hvor enig er du i følgende påstander

22. **Individuell konkurranse relatert til pensum øker elevenes motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

23. **Lagkonkurranser relatert til pensum øker elevenes motivasjon.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

24. **Under har du mulighet til å utdype svarene dine dersom du ønsker.**

For lærer

Hvor enig eller uenig er du i de følgende påstandene.

25. **Jeg ønsker å slippe å rette elevers arbeid om det kan gjøres automatisk.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

26. **Jeg ønsker et kontinuerlig oppdatert estimat av mine elevers ferdigheter.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

27. **Jeg ønsker friheten til å lage egne oppgaver kontra å gi oppgaver fra læreboka.** *
Mark only one oval.

	1	2	3	4	5	6	
Helt uenig	◯	◯	◯	◯	◯	◯	Helt enig

28. **Annet**
Om det er noe du har på hjertet, har du mulighet til å dele det her :)

A.1 Usability test plan

Preliminary questions

These questions try to uncover the extent of previous experience in regards to the participants use of digital tools in an educational context.

- Are you familiar with any learning management systems, learning games or other digital learning resources?
- Do you have a preference regarding learning from a regular text book or learning in a digital environment? Explain.

Tasks to be executed in the prototype

1. *Do one assignment in* Matriser/Brøkspill. *First answer incorrectly, get help, then find correct answer.* (T1)
2. *What are you best at?* (T2)
3. *Do you have any achievements? Which?* (T3)
4. *How many points do you have?* (T4)
5. *Change your profile environment to have purple hearts when you play* (T5)
6. *Change your profile environment to have a purple banner in stead of blue* (T6)

Final questions

The final questions are designed to give direct feedback on certain design elements or gamification elements. The questions could also be a starting point for a longer conversation with the participants.

- Would you say the prototype is easy to use and understand?
- Would you have preferred it rather than assignments from a text book?
- How do you experience receiving points for doing assignments?
- Did you feel the hints were helpful?
- How noticeable do you like the feedback for correct/incorrect answers to be while in-game?
- If you could choose freely from the assignments at hand, which would you choose to do?

A.2 Usability tests in detail

- **Participant 1 (P1)**

  Answers to preliminary questions:

  - P1 had experience with LMS such as ItsLearning and canvas. Have played Kahoot in lectures. Quite happy with breaking up lectures with Kahoot.
  - Prefers to read on paper, and do assignments digitally. Likes having google at hand.

Performing the tasks: P1 looks around and clicks on all three tabs. Remarks that it is nice that there is a lot of whitespace. Leaves fewer distractions and not a lot of clicking to get to where you are going.

(T1) P1 finds the way to the tab with the assignments. Assumes that the circles with numbers next to each assignment are the maximum points one can achieve for completing the assignments. Finds the assignment which was the task at hand. Discovers the trophy with the number two alongside. At fist P1 thinks it is some other kind of points. Clicks through all the tabs again and ponders a bit, concludes that the trophy must be achievements.

Continues with the first task. Clicks on the circle that leads to the matrix game. P1 immediately displays shock about the piece of math. Gets stressed about not know how to solve it. The mediator tries to reassure P1 that is not about being able to solve it right now rather just looking at everything around the piece of math. P1 tries to drag a game tile into the assignment text. Finds that it does nothing and tries to click on the game tile instead. Found an incorrect answer as intended in the task. Comments that the little box telling you it was incorrect has a nice and supportive tone. Is quick to locate and click the help-button, P1 notices that there now is only two hearts that are red. Wonders if was because of asking for help or just answering incorrectly. Thinks the hearts mean that there is a total of three tries in the whole game. P1 does not notice the button with the text: 1 of 5, until the mediator asks how many tasks until the whole assignment is complete.

In the help pop-up P1 sees a video, assumes it is relevant to this specific assignment. Looks at the hint and thinks for a few seconds before clicking on the first line saying "Show me hint". Does not understand the hint, and gets a bit flustered. Tries to click on the other hints. Nothing happens as the prototype does not have this as an option. Again the mediator reminds P1 that it is okay, and that it was originally meant for IT students. P1 accepts this, and effortlessly closes the pop-up by clicking outside of its perimeter.

Mediator helps with the correct answer. P1 finds and clicks on it. Is happy to see the little box with the message that the correct answer is received. Instantly sees the circle indicating points inside the box. Is thrilled

to have received ten points. Remarks that it is a nice size on the box giving the message of incorrect/correct answer. Can undisturbed keep thinking about the assignment when the box is so small.

(T3) P1 can't find the achievements at first, even though P1 had seen them and commented on them earlier. P1 kept using the English term *achievements* rather than the the Norwegian word *Bemerkelser* which was used in the task. Eventually got the connection with the two terms and thus found the achievements. Would like to have the trophy icon next to the achievements in the performance tab. Looks closely at the achievements and says that it is nice that there is some fun and easy ones as well. (T2) On the other hand, P1 found the performance measures okay. Saw that the circle with "Grunnleggende sannsynlighet" was fullest and concluded that it must indicate highest skill. P1 points out that it might be difficult for some to have the performance measures as the start page, however, it is good that the circles displaying how much you have mastered is always green, and never red.

(T4) Seems to have made the observation about the points earlier, because P1 had no need to look to find out about the points. (T5 and T6) To change the profile environment P1 first tries to click on the profile picture. Then has a look through all three tabs. Looks at "XP-marked last". Recognizes the hearts from the matrix game. Puzzles at the name "XP-marked". Did not think it would natural to buy the changes. But gladly changes color on both the hearts and the banner with no problem. Looks enthusiastic about it. Immediately after those tasks are done P1 tries to change the profile picture the same way as the hearts and banner. Bursts out "This is not me" and points at the picture. P1 wants to change the profile picture, and says it was a shame it was not possible yet. P1 thought one had to buy with the points earned to unlock other colors and pictures.

Answers to post-questions:

- P1 considers the prototype to be easy to get to know.
- Would rather have done assignments online than in a book. P1 concludes that is is easier to get help when stuck and that it is more satisfying to get feedback on assignments straight away.
- Loves points! Is a competitive spirit.
- Regarding the hints it is difficult to say if they were helpful, as this was the first time P1 ever laid eyes on matrices. P1 says that Google would have been the next stop in trying to find help.
- P1 liked the size of the feedback pop-ups. The small size was good because P1 felt it wasn't a hindrance, could keep working on the task at hand or move on to the next. Would have liked a sound accompanied with positive feedback.
- On the question which assignment P1 would choose, P1 hesitated. Said that it would depend on what kind of assignment it was and on the motivation at the time. P1 said it would be between "Lage ditt eget snake-spill" or "Yatzy".

Other comments: P1 shares a couple of ideas that came to life after the run-through of the prototype:

- Teachers could give digital achievements or some kind of digital token to students for social behaviour at school.
- Unlock game time or other fun games through doing school work.

- **Participant 2 (P2)**

  Answers to preliminary questions:

  - P2 remembers playing a game in English class in primary school of the type drag and drop. Could not remember its name. It seemed like it was a positive memory, on account of P2 smiling and laughing. P2 says they also used a digital textbook from Cappelen Damm. At university P2 uses two digital learning tools. Sykepleier Pluss and Visible Body. P2 explains that Sykepleier pluss is a paid service, mainly for nurses attending a specific subject but many others use it as it is relevant for other students of medicine too. It is video lectures with nice looking animations for illustrating difficult sections. Several time P2 emphasize how useful it is. Visible body is a tool for learning about the body's physiology, anatomy, functions and muscles using a body in 3D view. A quiz function is available. Have also used Kahoot in lectures.
  - Prefers to read in traditional books, but favours tasks for practicing the reading material in a digital format.

Performing the tasks: P2 jumps in and starts by clicking on everything possible. Looked through all three tab. (T1) Found and started the assignment readily. Understood the points connected to the different assignments as either an indication of difficulty. P2 also considers that it might be how many possible points the assignments are worth. Halted when seeing the matrices. Started wondering how to do it. P2 first thought it was some odd looking fractions. The moderator reassured P2 that solving it wasn't too important. P2 was still rattled by the fact that it unknown math. After clicking on an incorrect answer P2 was quick to find and click the help-button. Didn't look too closely at the pop-up saying the answer given was incorrect. Saw where to find hints and clicked to get the help pop-up opened. Overlooked the video completely. Showed signs of frustration with the hint that was revealed when P2 clicked on it. P2 felt it was too little information. At this point P2 noticed that one of the hearts in the game lost its color. Thought it was due to either resorting to using a hint or answering incorrectly. Exits the help pop-up without hesitation. Mediator reveals the correct answer and P2 clicks on it. Registers the pop-up telling it is the correct answer and that 10 points was earned. Dismisses is quickly, and exits the assignment by clicking on the cross in the upper right corner.

Looks at trophy and (T4) the points that are located next to the profile picture in the upper left corner of the screen. Thinks the trophy indicates that an assignment was done perfectly. And understand the points

correctly. (T3) Easily locates the achievements and points out which are completed. Tries clicking on the achievements. Expects more information when clicking on them. (T2) P2 has a hard time finding out what skill has the highest mastery level. First instinct is to look in the tab with the assignments, then moves past the performance measures goes to the achievements, and finally discovers the performance measures under the same tab as the achievements. It takes one glance for P2 to decide that probability is the skill with the highest mastery level.

(T5 and T6) No hesitation in the next two tasks; changing the profile environment. Goes straight to the tab "XP-marked", and seamlessly navigates through changing the hearts and the banner. Assumes the the unavailable elements are locked and will be unlock by earning more points.

Answering post-questions:

- P2 finds the prototype easy to navigate.
- Says that if it had been relevant to P2s subjects, a little like Visible body, it would have been better than a book with assignments.
- Enjoys receiving points, and points out that it is motivating to use them on something like colors and such.
- Was a bit unsure if hints in such a format would be helpful. When P2 was shown the video next to the hints P2 was surprised that it was overlooked. P2 deemed a video to be more helpful than the hints as they were at the time.
- Liked the way the feedback for right and wrong was given, and it was a good size on the message.
- Would have a chosen to do "Lage ditt eget snake-spill" if P2 could choose. P2 said it looked fun. It was a choice between that and Yatzy.

Other comments: No other comments

Changes were made to the prototype

A few modifications were done after the first two tests were completed. Firstly, the assignment was swapped out with a simpler fraction assignment. Secondly, the trophy icon indicating achievements collected were put next to the title in the section with achievements as well. To make it symmetrical the section with skills also got an appropriate icon next to its title.

- **Participant 3(P3)**

  Answers to preliminary questions:

- From elementary school P3 remembers using a memory game. Mostly as a treat for when everything else was complete. P3 describes the game as having a 90's feels to it. In upper secondary school P3 used Cappelen Damms Passage and their internet resources. Also this was only used when all work in the primary curriculum was covered. In private P3 have spent some time using CodeAcademy to learn to code. At university digital flash card services were utilized for rehearsing material. P3 had a professor who used Kahoot to test his students. P3 was less than satisfied with the way Kahoot was used, and felt it was incorrect and unfair.
- Much prefers reading and doing exercises in traditional books. Says reading on paper is more comfortable and less likely to be distracted than if a laptop was involved.

Performing the tasks:

When handed the laptop with the prototype P3 starts by having a long look at the home screen, the skills tab. Registers that the circles have percentages and concludes that it must be an indication on progress. Tries to click on them. Moves on to go to the achievements further down in the tab. Understands them correctly to be achievements. (T1) Tries to return to the start, further up in the skills tab, by clicking on the skill tab. It was a flaw in the prototype after the changes had been done. P3 gets a little confused, but moves on. Clicks the assignment tab and spots the correct assignment quickly. Doesn't quite know what the numbers on the assignments mean. P3 feels they are a little wage. Thinks they might indicate total amount of points that can be achieved. Or an indication on how much work each assignment is. Clicks the assignment *Brøkspill*. Immediately starts to solve the fraction. Is positive towards solving the fraction as this is something P3 knows how to do. Explicitly says so. Remembers to first fail and then find help. Notice straight away that a heart turn grey when answering incorrectly. Exclaims: "Oh, I lost a life!". Does not seem to notice the pop-up saying the answer was incorrect. Easily finds the help-button on the bottom right of game. Presumes the video that is available to watch in the help pop-up is about the fundamentals of adding fractions. Whereas P3 expects the hints to be more hints step by step to the specific task. Takes a moment before deciding to how to close the help pop-up, but clicks outside it perimeter. Finds and clicks on the correct answer. This time P3 sees the pop-up in the bottom left corner with praises for the correct answer and the awarding of ten points. Would have like to have clearer feedback here. Suggests color coding. Green for completely correct on first go, yellow for correct on the second try and red for completely wrong. Does not spot how many tasks were needed to complete the whole assignment naturally, but does when asked to look for it. Exits the assignment fine by clicking the cross in the upper right corner. Comments that the return to the assignment tab was expected, felt natural.

P3 doesn't start the next task right away, but rather explores a bit more with no purpose. Discovers the tab "XP-marked", doesn't seem to think too hard on it and moves on to the skills tab. Starts the task of finding

what is the strongest skill for P3 aka Nora Hermannsen.(T2) As P3 is already in the skills tab, this was no trouble. P3 comments that it could be that the circles with percentages are indicators of how far one has gotten in the various assignments, but dismisses that because P3 doesn't feel there is an obvious connection with the assignments in the assignment tab and the titles of the circles in the skill tab. Concludes that basic probability is the strongest branch of knowledge based on that the circle with the title "Grunnleggende sannsynlighet" has the highest percentage and is more green than the other circles.

(T3) Naturally navigates down the skill tab by clicking the downwards facing arrow at the bottom of the page to find the achievements. Is quick to say 7 achievements have been collected. Then hesitates a few seconds and takes a closer look and notes that there is more color on some of the achievements and adjusts the answer to two. P3 would like stronger colors on the achievements that are collected. P3 detects the golden trophy with the number two next to the profile picture up to the left on the screen. This is the affirmation P3 needs to be confident with the answer given about number of achievements collected. (T4) P3 was aware of how many points were earned already from the start even though the golden trophy was overlooked until the task of finding the achievements. Comments that the word XP has a gaming association for P3.

(T5 and T6)Now with the word XP and gaming in mind P3 says that there is an expectation that the "XP-marked" tab is an overview of the points earned; details about the composition of the points. E.g. 10 points earned playing the *Brøkspill* today or the majority of the points come from learning basic probability. Here P3 draws a connection to statistics about characters in (MMO)RPG games. The expectation is not met when clicking "XP-marked". P3 admits that the word "marked" did not really sink in at first, but that is makes sense as this tab is shop-like. Unhindered solves the tasks of changing the red hearts to purple and the banner from blue to purple. Assumes that when earned 300+XP the remaining color and banner option is available to choose from as well.

Answering post-questions:

- P3 said the layout was functional, however, the design was rather dull and flat.
- "I remember I always started with the subjects I enjoyed the most, history and Norwegian, and so the other subjects suffered "
- P3 liked that the points had a purpose. P3 thinks back to the early 2000s when points were collected for the sole purpose of manually comparing highscores with others. And said it now seems like younger people have higher expectations of everything regarding games and other digital tools.
- Was unsure about how helpful the hints would be compared to Google. Found the idea of help in such a fashion okay, but P3 felt confident enough to look for help other places.

- Would have liked to get the feedback on the result of the task performed much larger and in the middle of the screen.
- Would definitely have chosen to do "Lage ditt eget snake-spill". The reason being its novelty, P3 said it seemed to be different from everyday school work.

Other comments:

- P3 suggests having the assignment tab as the home screen, saying that it is the main activity in the prototype and therefore feels more suitable. Another suggestion is having a more distinctive home screen altogether. P3 could not specify any more on the subject. P3 reckon a dedicated profile page should be available by clicking the profile picture. Does however not know what it should contain. Proposes that maybe the skills and achievements could be put there.
- Regarding the unlocking of customization options for the profile environment, P3 also advocate for unlocking games and other fun activities. Enthuses that it is motivating to gather points when you see others playing a cool game next to you.
- P3 thinks the pop-up for giving feedback on whether the answer in the game is correct or not is too small and hidden. Says it is reminiscent of a cookie notification most websites have now, and those are mostly click on to make them go away. Hence, P3 feels that is the reason not noticing the first one.
- P3 feels that helping learners manage time on subjects that doesn't come naturally to them is gold;

  > "I remember that I always started with the subjects that I enjoyed and did well when doing homework. Then, at the end I didn't have much time to do the rest in the other subjects."

  This was a reflection P3 had when discussing the assignments having different values (XP) based on the skill of the learner as an incentive to practice weaker skills as well. This got an enthusiastic response from P3. Points and the unlocking of fun things with the points P3 felt would be a nice reward and motivating to strive after in the everyday.

Bibliography

[1] Andrzej Marczewski. Game based solution design. https://www.gamified.uk/gamification-framework/differences-between-gamification-and-games/.

[2] Gyldendal Undervisning. Kom i gang med lærerstudio. https://www.gyldendal.no/grs/Salaby/Salaby-Laererstudio2/Kom-i-gang-med-Laererstudio#.

[3] Kunnskapsdepartementet. Framtid, fornyelse og digitalisering digitaliseringsstrategi for grunnopplæringen 2017–2021. 04 2017.

[4] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: Defining gamification. volume 11, pages 9–15, 09 2011.

[5] Nick Pelling. Nick pelling - gamification, past and present. video https://www.youtube.com/watch?v=h-bwMTR4tfg.

[6] Forest app. https://play.google.com/store/apps/details?id=cc.forestapp.

[7] The fun theory. https://goodvertising.site/the-fun-theory/.

[8] Gartner Inc. The pace of change will never be this slow again. https://www.gartner.com/en/about.

[9] Brian Burke. Gartner redefines gamification. https://blogs.gartner.com/brian_burke/2014/04/04/gartner-redefines-gamification/.

[10] Patrick Buckley and Elaine Doyle. Gamification and student motivation. *Interactive Learning Environments*, 10 2014.

[11] Susan Krauss Whitebourne. Motivation: The why's of behaviour. https://www.psychologytoday.com/intl/blog/fulfillment-any-age/201110/motivation-the-why-s-behavior.

[12] Deci E. L. Ryan, R. M. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55, Jan 2000.

[13] Saul McLeod. Operant conditioning. https://www.simplypsychology.org/operant-conditioning.html.

[14] Pelletier L. G. Blais M. R. Briere N. M. Senecal C. & Vallieres E. F. Vallerand, R. J. The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, 52(4):1003—-1017, 1992.

[15] Lisa Legault. *Self-Determination Theory*. 06 2017.

[16] Professor edward deci on self-determintation theory. https://vimeo.com/37460250, February 2012.

[17] Sascha Schneider, Steve Nebel, Maik Beege, and Günter Daniel Rey. The autonomy-enhancing effects of choice on cognitive load, motivation and learning with digital media. *Learning and Instruction*, 58:161 – 172, 2018.

[18] Min Jeong Kang, Ming Hsu, Ian M. Krajbich, George Loewenstein, Samuel M. McClure, Joseph Tao yi Wang, and Colin F. Camerer. The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological Science*, 20(8):963–973, 2009. PMID: 19619181.

[19] Raph Koster. *Theory of Fun for Game Design*. O'Reilly Media, Inc., 2nd edition, 2013.

[20] Matthias J. Gruber, Bernard D. Gelman, and Charan Ranganath. States of curiosity modulate hippocampus-dependent learning via the dopaminergic circuit. *Neuron*, 84(2):486 – 496, 2014.

[21] Yu kai Chou. Points, badges and leaderboards: The gamification fallacy. https://yukaichou.com/gamification-study/points-badges-and-leaderboards-the-gamification-fallacy/.

[22] Biyun Huang. Do points, badges and leaderboard increase learning and activity: A quasi-expermiment on the effect of gamification.

[23] Mihaly Csikszentmihalyi, Sami Abuhamdeh, and Jeanne Nakamura. *Flow*, pages 227–238. Springer Netherlands, Dordrecht, 2014.

[24] Wikipedia. Civilization v. https://en.wikipedia.org/wiki/Civilization_V.

[25] Wikipedia. Freecell. https://en.wikipedia.org/wiki/FreeCell.

[26] Brynne C. DiMenichi and Elizabeth Tricomi. The power of competition: Effects of social motivation on attention, sustained physical effort, and learning. *Frontiers in Psychology*, 6:1282, 2015.

[27] Kevin A. Harrigan, Karen Collins, Michael J. Dixon, and Jonathan Fugelsang. Addictive gameplay: What casual game designers can learn from slot machine research. In *Proceedings of the International Academic Conference on the Future of Game Design and Technology*, Futureplay '10, pages 127–133, New York, NY, USA, 2010. ACM.

[28] Saul McLeod. Skinner - operant conditioning. https://www.simplypsychology.org/operant-conditioning.html.

[29] Roger Azevedo, Jennifer G. Cromley, Fielding I. Winters, Daniel C. Moos, and Jeffrey A. Greene. Adaptive human scaffolding facilitates adolescents' self-regulated learning with hypermedia. *Instructional Science*, 33(5):381–412, Nov 2005.

[30] Azevedo Roger, Jennifer Cromley, Daniel Moos, Jeffrey Greene, and Fielding I. Winters. Adaptive content and process scaffolding: A key to facilitating students' self-regulated learning with hypermedia. *Psychological Test and Assessment Modeling*, 53, 03 2011.

[31] Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23):8410–8415, 2014.

[32] Yael Sharan. Cooperative learning: a diversified pedagogy for diverse classrooms. *Intercultural Education*, 21(3):195–203, 2010.

[33] Harvey F. Silver, Richard W. Strong, and Matthew J. Perini. *The Strategic Teacher : Selecting the Right Research-Based Strategy for Every Lesson*. Merrill Education/ASCD College Textbook Series. ASCD, 2007.

[34] Jacob Lowell Bishop, Matthew A Verleger, et al. The flipped classroom: A survey of the research. In *ASEE national conference proceedings, Atlanta, GA*, volume 30, pages 1–18, 2013.

[35] Audrey L. Amrein and David Berliner. The effects of high-stakes testing on student motivation and learning. *Educational Leadership*, 60, 02 2003.

[36] American Psychological Association. Appropriate use of high-stakes testing in our nation's schools. American Psychological Association.

[37] Mary Lee Smith and Patricia Fey. Validity and accountability in high-stakes testing. *Journal of Teacher Education*, 51(5):334–344, 2000.

[38] Daniel M Koretz et al. The effects of high-stakes testing on achievement: Preliminary findings about generalization across tests. 1991.

[39] Sean H. K. Kang. Spaced repetition promotes efficient and effective learning: Policy implications for instruction. *Policy Insights from the Behavioral and Brain Sciences*, 3(1):12–19, 2016.

[40] Doug Rohrer and Kelli Taylor. The effects of overlearning and distrubted practise on the retention of mathematics knowledge. *Applied Cognitive Psychology*, 20:1209 – 1224, 12 2006.

[41] NTNU. Digimat. https://www.ntnu.no/wiki/display/digimat/.

[42] Stanley H Erlwanger. Benny's conception of rules and answers in ipi mathematics. *Journal of Children's Mathematical Behavior*, 1(2):7–26, 1973.

[43] M. Ibáñez, Á. Di-Serio, and C. Delgado-Kloos. Gamification for engaging computer science students in learning activities: A case study. *IEEE Transactions on Learning Technologies*, 7(3):291–301, July 2014.

[44] G. Barata, S. Gama, J. Jorge, and D. Goncalves. Engaging engineering students with gamification. In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, pages 1–8, Sep. 2013.

[45] Regjerningen.no. Framtid, fornyelse og digitalisering. https://www.regjeringen.no/no/dokumenter/framtid-fornyelse-og-digitalisering/id2568347/.

[46] Gyldendal. Velkommen til salaby. https://www.gyldendal.no/grs/Salaby.

[47] Jonas Blich Bakken. Får ti milioner av aschehoug for å utkonkurrere mattebøker. https://www.dn.no/teknologi/anders-baumberger/vegard-vik/ulv-pedersen/far-ti-millioner-av-aschehoug-for-a-utkonkurrere-matteboker/2-1-248624.

[48] Campus Inkrement. Om campus inkrement. https://campus.inkrement.no/Home/About.

[49] Nils Kåre Jacobsen. Børs og katedral. https://www.gyldendal.no/Om-Gyldendal/Boers-og-katedral.

[50] Aschehoug. Hvem er vi? https://www.aschehoug.no/Om-Aschehoug/Hvem-er-vi.

[51] Cappelen Damm. Cappelen damms historie. https://www.cappelendamm.no/cappelendamm/om-forlaget/article.action?contentId=39309.

[52] Helena de Bertodano. Khan academy: The man who wants to teach the world. https://www.telegraph.co.uk/education/educationnews/9568850/Khan-Academy-The-man-who-wants-to-teach-the-world.html.

[53] Google. Design. https://material.io/design/.

[54] Google. Crazy 8's. https://designsprintkit.withgoogle.com/methodology/phase3-sketch/crazy-eights.

[55] Google. Dot vote. https://designsprintkit.withgoogle.com/methodology/phase4-decide/dot-vote.

[56] Jennifer DeRome. Moderated vs. unmoderated usability testing: The pros and cons. https://www.usertesting.com/blog/moderated-vs-unmoderated-usability-testing/.

[57] Usability.gov. Reporting usability test results. https://www.usability.gov/how-to-and-tools/methods/reporting-usability-test-results.html.