Using Internet of Things to enhance learning

A study about how IoT-based functions could manage current challenges in upper secondary school environment

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Abstract

The digitalization is spread out in society and it affects all kinds of social areas, including the school environment. This entails altered circumstances in school, which in turn modifies certain challenges and the school system needs to adapt accordingly to that. The ability to *keep focus* and *the motivation to start with school tasks* are challenges that have been affected by the digitalization and that has an impact on learning. Internet of Things (IoT) has shown to possess a large potential to manage with societal challenges, but research is lacking about how it can be used in a school environment to enhance learning. *This study intends to understand current challenges in school and to find out how IoT could be used to manage these challenges.* This study initiated with the guidelines of design-based research (DBR), where upper secondary school teachers were used as participants in order to collect representative data. Findings showed that IoT could be used to manage the challenges of focus and motivation, by using different functions as a system. A low fidelity prototype was developed where its main functions intend to interact with each other and with the student in order to assist the student to keep focus and to gain motivation. The findings were considered as valuable and could be used as an indication to future IoT-implementations in school, about which challenges to address and how IoT could be used.

Keywords: Internet of Things, digitalization, education, learning, school, prototype, focus, motivation.

Synopsis

Background

The ongoing digitalization affects society and school in a way that changes circumstances and the school needs to adapt accordingly in order to retain its purpose. Challenges as focus loss and motivation have an impact on learning and require adequate solutions when managing them. Internet of Things possesses a large potential to provide with effective solutions to current challenges. Research is lacking for how IoT could be used in school, especially regarding pre-university educations. Allowing active teachers to identify current challenges brought by digitalization and also letting them suggest potential solutions based on IoT could contribute to a powerful indication on what is wanted and what could be done.

Problem

With the ongoing digitalization in society overall, challenges alter and the situation in school is no exception. A changing environment affects the student's behavior and in regards to the enhancement of learning in school, IoT has a lot of potentials to be used for that purpose. The current challenges in school need to be acknowledged and new opportunities need to be explored.

Research Question

Based on challenges that have emerged in school from the digitalization, how could IoT be used to enhance learning according to upper secondary school teachers?

Method

With an intention to conduct design-based research (DBR) strategy, a mix between theory and empiricism contributed with a ground to develop a prototype. Collected data from focus groups held with teachers provided the perspectives from the school environment. In total, 10 teachers participated in the two focus groups. The collected data was analyzed with content analysis in order to extract and gather the most crucial parts in the qualitative data. The prototype was evaluated by conducting a semi-structured interview with an expert in the school area.

Findings

According to the participating teachers, several different challenges affected by digitalization exist. Two of these were focus-keeping and motivation gain in school activities. An IoT-based system was developed to handle both these challenges and was evaluated to have a great impact to enhance learning. The system is intended to help the student by providing: *different suggestions to keep focused*, *show accomplishments*, *show an activity feed* and *showing encouraging statistics.*

Discussion

The chosen DBR-strategy was not optimal for use in this study. In larger studies with more resources, DBR is considered to fit better. IoT provides a great number of possibilities and the potential is very large to take part as an important actor in the modern school environment. The developed prototype and its functions intended to manage the challenges of focus and motivation. Both the challenges and the IoT-functions were collected from active teachers, which gives the findings relevance.

Conclusion

IoT could be used in the form of making it possible for a system to learn about *student behavior* and *student performances* by collecting relevant data. By combining and analyzing this data, the IoT-system could help students by providing different *suggestions to keep focused*, *show accomplishments*, *show an activity feed* and by *showing encouraging statistics*. Providing students with this is considered to contribute with better circumstances to keep focus and to raise motivation, and by that; enhance learning.

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1 Introduction

This study concentrates on exploring what kind of Internet of Things (IoT) -interventions could be implemented in Swedish school in order to enhance learning. A qualitative approach with a methodology of Design Based Research (DBR) was chosen for the purpose of this study with the intention to fully grasp the current situation in schools and to thoroughly suggest relevant solutions. This study is part of a larger scale science project named IoT Hubb (IoThub.se) with an aim to develop the possibilities and potential with IoT in school and in education environments. Several actors are included in the IoT Hubb project, where one of them are Stockholm University and its Department of Computer and Systems Sciences (DSV). The involvement from DSV has made it possible for this study to interact with experts in the area. A publication made by Hernwall and Ramberg (2019) for the IoT Hubb project has functioned as an inspiration for this study in its structure as well as in its execution and the fundamental understanding of IoT.

Important for this study was to capture opinions and reflections from teachers who experience the school environment regularly and from their mindsets lay a ground to the result in form of current challenges and possible solutions. The DBR-methodology used this ground to form and suggest a prototype. The participating teachers in this study were from an upper secondary school with technological and innovative orientation. However, that does not guarantee an in-depth knowledge about technological innovations from the teachers.

An indication to what is wanted, needed and relevant in terms of IoT in school will form the result of this study. This could be interesting to use for several actors such as researchers within IoT-interventions or politicians working with school development - to use as an indication or steppingstone to future work. The participation and contribution from active teachers makes the result a relevant and important indication to consider when proceeding with implementations of IoT in school.

Technological advances and implementations tend to be the solution when searching for improvement in performance. Services within society have been affected by digitalization to such an extent that it has been embedded within infrastructures or societal entities such as banking and electrical grid management (Dufva & Dufva, 2018). Included in the digitalization-term is an overall automation and technology development to everyday activities covered by different kinds of information technologies (IT), where one area of technology is the Internet of Things (IoT).

The specific area of IoT is defined differently in different studies and media (Saritas, 2015; Uzelac, Gligoric & Krco, 2015) and it is difficult to draw boundaries on what could be seen as an IoT-intervention and what cannot. Uzelac et al. (2015) mention a definition that is rather broad, yet it explains the basics with Internet of Things (p. 428):

> *"A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies."*

Internet of Things can hence be applicable to many technologies where an important aspect is the ability to communicate with other physical or virtual objects and thereby exchange and use retrieved data to, inter alia, solve a problem or to generate other certain outputs. The formulation of the definition describes the interconnection between objects but lacks an important dimension, which is the interaction with humans. Broadening the definition to include the involvement of humans in the interaction opens up for new opportunities on how to benefit from the collected data.

School is an entity that does not fall short on the technology and IoT-solutions possibility list. A Swedish study, performed in the northern town of Skellefteå, intended to test different IoT-approaches in order to relieve the teacher of the experienced burden of taking attendance. One of the two used methods was a beacon technology that would pick up signals from tags carried by the students. The other method was facial recognition were each student's face was scanned when they entered the lecture room to document their attendance. The study showed that teachers could escape the time-consuming process of taking attendance manually, which would allow them to spend more time on the actual teaching and with that; enhance learning (Tieto, 2018). A fear of technology that existed initially with the students in the Skellefteå case, especially towards facial recognition, evaporated during the project where excitement took its place. That study was an example of how IoT could be used within school settings to enhance learning and at the same time improve the school environment.

The changing environment caused by digitalization brings challenges to organizations needing to adapt, which also applies to schools. Pettersson (2018) mentions that the transformation to a digitalized school requires fundamental changes in the structure of the current school system as well as in cultural aspects and visions. Sharples (2016) mentioned that if a teacher from the 19th century had entered a classroom in the early 1990s, that teacher would have recognized the environment. If that same teacher had entered a classroom twenty years later, the teacher would not recognize as much, according to Sharples (2016). With that, Sharples (2016) implied that digital development in school has entered drastically during the last decades and many new possibilities open up regularly with the ongoing digitalization (Dufva & Dufva, 2018).

The Internet of Things (IoT) lies in the heart of digitalization today, acting as a vital component in future technologies (Lee and Lee, 2015). The usage of IoT is rapidly increasing. It is mentioned by Lee and Lee (2015) that IoT is predicted to have 26 billion units in 2020, an increase from 0.9 billion units in 2009. Another prediction is mentioned by Saritas (2015), referring to the amount of connected smart devices reaching up to 50 billion by the year 2020. This vast increment will presumably affect society, including the school system to an extent where new tools will be required in order to maintain a healthy and productive learning environment that reflects with reality. Internet-enabled devices are emerging every day in the consumer industry and according to Saritas (2015) IoT will eventually find its place in various learning environments. Continuing, Saritas (2015) argue that the potential of IoT is attractive to educational institutions and educators as it e.g. encourages and simplifies the contact between students and teachers as well as simplifies the sharing and access to digital content.

1.1 Background

Schools have an important purpose in society. The *Swedish national agency of education* (2018) described in the curriculum for Swedish elementary school, that the school's mission is to enhance learning and by that prepare students to live and act in society. This entails that the school should be a reflection of society by following and adjusting to the development of society. It is further mentioned in the curriculum that the school should help the students to understand the effects from the digitalization on society and the impact it has on individuals (Swedish national agency of education, 2018). The impact from the digitalization on school is confirmed by Mårell-Olsson & Bergström (2018), stating that digitalization has changed the working conditions and the overall organization. Pettersson (2018) also stated that school and learning activities are affected by the change in the environment brought by digitalization, which indicates that the entire school system is changing and adapting to a digital society.

Several countries around the world have invested in digitalization in school, where Sweden is one of the leading countries in having the best access to usable technology (Malmberg & Helmersson Olsson, 2016). However, Sweden is mentioned to have fallen behind when it comes to the usage of technological interventions in school (Malmberg & Helmersson Olsson, 2016). Having access to technology but at the same time not using it to its full capacity raises some questions about how that can be the case.

Falling behind with the usage of technological interventions in school does not necessarily mean that the development is going in a negative direction. On the contrary, Sweden is progressing its technological usage in school, where for instance the number of available computers was one per student in upper secondary schools in 2016 (Malmberg & Helmersson Olsson, 2016). In other words, Sweden has access to technology and utilizes the available technology to some degree, but there is a lot left that could be done with the opportunities that technology brings.

With support from a digitalization strategy set by the Swedish government, Sweden is striving to become the leading country in the usage of technology in school. The digitalization strategy was formulated by the Swedish ministry of education (2017), where the goal was stated as follows (p. 4):

> "*The Swedish school should be leading in using the digitalization opportunities in the best possible way, in order to reach a high digital competence with children and students in order to enhance knowledge development and equivalence.*"

Digital competence is a central part of the goal and the term was described as the degree of familiarity with digital tools and services, and the ability to remain updated in the digital development and its impact on society (Swedish ministry of education, 2017). In relation to the stated goal for the Swedish digitalization strategy, where an increment of digital competence is centered, Malmberg & Helmersson Olsson (2016) mentioned a study by Krumsvik et al. (2013) who noticed a correlation between teacher's digital competence and students school results. Krumsvik et al. (2013) concluded, inter alia, that an increment of teacher's digital competence plays an important part to increase students usage of digital tools, which in its turn was considered to improve students school results.

There have not only been positive reactions towards the set *digitalization strategy* and the central term of *digital competence*. Different people with knowledge about the school area have addressed criticism towards both the strategy as well as the term. The criticism has for instance been about unclear strategic guidelines for how to actually reach an increased digital competence and also that the definition presented for the term *digital competence* is very vague (Lindström, 2017; Skogstad, 2018). Despite some criticism, the digitalization strategy stands as a ground towards reaching the national goal of making Sweden the leading country on using the opportunities brought by digitalization.

The digitalization strategy was set in 2017 and in January 2019, the Swedish prime minister suggested a ban of the use of mobile phones in school (SVT, 2019). This statement leads to questioning the stated directives in the *digitalization strategy*, wanting to increase the usage of digital tools. The underlying problematic of distraction from mobile phones is mentioned by Malmberg & Helmersson Olsson (2016) where they state that two-thirds of teachers in Swedish elementary and upper secondary school experience a disturbance on school work from text messages, social media, etc. The distraction from mobile phones is also noticed by the Swedish national agency of education (2019), who however stated that mobile phones could instead be used as powerful tools in school work. Ott et al. (2017) stated that the mobile phone does have a split impact where it simultaneously creates challenges and possibilities in the student's infrastructure for learning. It is further mentioned by Ott et al. (2017), referring to a study by Berry and Westfall (2015), that the main discussion should be about how to integrate mobile phones instead of prohibiting them. This integration of mobile phones is more in line with the digitalization strategy directives about finding ways to increase the usage of all digital tools, and not prohibiting them.

The debate about mobile phones illustrates an indication that more research is required about how technology overall could and should be used in school purposes. An area within technology that is considered to have a large potential to manage challenges in school is IoT (Saritas, 2015; Moreira et al, 2017).

Entailed benefits and a large potential is seen with IoT-interventions (Saritas, 2015; Moreira et al, 2017), which suggest that IoT could provide with powerful solutions for current challenges in school and at the same time; enhance learning in school environment (Gomez et al, 2013; Moreira et al, 2017). Despite the *large potential with IoT-implementations*, the ongoing *expansion of IoT-interventions in the rest of society* and *digitalization overall*, IoT-implementations in school is something that is rarely seen, especially in pre-university education levels (Saritas, 2015; Lee and Lee, 2015).

1.2 Research problem

The ongoing digitalization creates a change of circumstances in today's society, which in turn causes emerged and modified challenges. Schools are not immune to this effect and must adapt to their new environment like most entities of the society. A vital function of schools is to prepare students for the future and thus, the school structure and its environment needs to be a reflection of society in order to properly contribute with knowledge that is necessary for the students. When it comes to facing challenges that could affect learning in school, such as focus keeping and motivation, IoT is considered to possess a large potential in providing powerful solutions. An important objective in the challenge management should be to enhance learning. With a lack of research performed, about IoT-implementations to enhance learning in pre-university education levels such as upper secondary school, a need exists to investigate the possibilities on how to use IoT in today's school with the intention to enhance learning.

The addressed problem in this study is hence that emerging challenges in today's school, arisen from the ongoing digitalization of society could affect students negatively and eventually affect their learning. IoT has a large potential to solve different societal challenges but research is lacking about how it can be used in pre-university education levels, in order to deal with challenges in school and to enhance learning.

1.3 Aim and research question

The aim of this study is to understand challenges that have arisen due to the digitalization and to suggest an IoT-based intervention that can be used to enhance learning, all based on opinions and ideas collected from active teachers.

RQ: Based on challenges that have emerged in school from the digitalization, how could IoT be used to enhance learning according to upper secondary school teachers?

1.4 Extended background

Facing the situation that society is currently in a digitalization-era (Saritas, 2015) implies that also school and learning activities are affected by this change in environment (Pettersson, 2018). The intention of wanting to digitalize the school has existed during a longer period in Sweden. Fransson et al. (2018) presented a timeline starting in 1983 where a regulation about the state financial affairs included an appendix indicating that computer science should be taught in second grade. All along through this timeline, it could be noted that school has felt an increasing presence from the digitalization in society (Fransson et al, 2018) and by that it has been affected in a way where structural, cultural and educational aspects require transformation, both in classrooms and in organization (Pettersson, 2018).

Hansson (2013) stated that the ongoing technological development does affect society and its institutions, leading to altered circumstances. These altered circumstances caused by digitalization yields for the school system as well, and it affects all the teachers, school leaders, students and even student's parents (Hansson, 2013). With changed circumstances and a changing environment, new challenges emerge in school (Pettersson, 2018). These emerged challenges brought by digitalization could be in form of *new ways of following policies* (Fransson et al, 2018) or *changed causes of distractions* (Malmberg & Helmersson Olsson, 2016).

Focus keeping

The loss of focus could be such a challenge that has been affected by the digitalization. It has been shown that a loss of focus has an impact on learning (Egong, 2014). A study conducted by Egong (2014) showed that students with the ability to stay focused during longer periods performed better in academic tasks than students that had difficulty with concentration. Based on the assumption that there is a correlation between academic performance and learning, the study of Egong (2014) indicates that focus affects learning. Focus could be interpreted in different ways and to be clear about what is meant with focus in this study; a stipulative definition to the term *focus* was set by the authors as:

"Students ability to maintain concentrated during the conduction of school-tasks"

The focus issue is not a new occurrence, but its causes have most likely shifted with time. Malmberg & Helmersson Olsson (2016) mentions that increased access to computers and internet, leads to an increased risk for students to lose focus on school tasks by doing something else, e.g. games or social media. Malmberg & Helmersson Olsson (2016) further argues that the risk of distraction has increased substantially with the many possibilities that digitalization provide.

A study by Jacobsen & Forste (2011) concluded that 62% of the students that participated in their study use electronic media for non-academic purposes during occasions that were intended for studying. Jacobsen & Forste (2011) also mentions that there is an upward trend in digital activity, where student generations increase their activity with time. This could indicate indirectly that the distraction from electronic media occurs to a higher extent today (2019) and that digitalization does have an impact on focus keeping. The causes to focus-loss today could therefore be caused to a large extent from electronic devices, which could not have been the case before the digitalized society. This shows that the digitalization affects challenges in school by changing the causes of them occurring.

An example of a cause of distraction from digital media could be push notifications. A study by Kallookaran & Robra-Rizzants (2017) showed that the distractive nature of notifications could be replaced to a more assistive nature where notifications could help and guide students instead. It was shown that push notifications could be used to help students to follow a study schedule and in that way not fall behind. Kallookaran & Robra-Rizzants (2017) developed an application that allowed students to subscribe to courses and by that; receive push notifications about upcoming course-events. In that way, the students were reminded about upcoming learning sessions, which were considered to be crucial in order to keep the student in line with schedule (Kallookran & Robra-Rizzants, 2017). This shows how digitalization does not only emerge and modify challenges; it also shows how it could create great opportunities. Notifications could be seen as a distraction from digital devices but in the case by Kallookran & Robra-Rizzants (2017), notifications functioned as taught valuable assistance instead and helped students to stick to their schedule.

Motivational gain

Student motivation is an aspect that tends to have a positive impact on the student's ability to achieve success in learning (Rahardjanto, Husamah and Fauzi, 2019). Alhadi and Saputra (2017) support this statement through their study to quantify the influence motivation has on student learning. The study was performed as non-experimental research and used correlational design with 515 students to estimate that learning outcomes are determined by 21.5% of learning motivation. The term "motivation" is a diversive term and could include many characteristics. Tuan, Chin and Shieh (2005) mentioned some of them as *self-perception of competence*, *self-efficiency*, *intrinsic goal orientation, task value* and *effort*. They went on to mention that the diversity of the term might highlight an issue of researcher bias when approaching the aspect of motivation.

A stipulative definition of the term *motivation* was by the authors of this study as:

"*Students engagement and willingness to start with school tasks.*"

Dislen et al. (2013) stated that despite the complexity of defining *motivation*, in school matters; motivation could provide the students with a clear direction to follow. It was also stated that motivation exist as one of the significant backbones of learning process in student life (Dislen et al, 2013). Identifying the causes of decreased motivation and finding out how to handle those is therefore of importance (Dislen et al, 2013). A negative attitude towards school was noted by Prensky (2003), while the attitude towards digital media, such as games, instead was considered to be very positive. The difference in attitudes might suggest that students are more motivated to play digital games than conducting study tasks. The cause of the attitude difference was described by Prensky (2003) to possibly be due to certain characteristics that games possess and the school does not. Examples of these characteristics were that games are *competitive, cooperative* and *results oriented* and Prensky (2003) meant that school should strive to obtain similar characteristics in learning, to retain positive attitude towards school.

A correlation between student motivation and student achievement was shown in a study performed by Arens et al. (2015). They examined the relationship between classroom disciplinary problems and motivation. The motivational aspect was divided into three core outcomes through a multidimensional approach: self-perception of competence, test anxiety and engagement. Each of these motivational aspects proved to have a direct impact on student's achievements. Self-perception of competence showed to be subject-related, meaning that a student's self-perception about its mathematics competence had a greater impact on *Mathematics* achievements than on *English* achievements. The impact that these motivational aspects proved to have on student achievements leads to the assumption that motivation has the same impact on learning.

IoT in education

Having concluded that the digitalization has brought new circumstances and hence new challenges in school, modern ways of managing these challenges are considered to be preferred in order to not complicate learning (Swedish national agency of education, 2019a). To use modern tools is also in line with the Swedish *digitalization strategy* and supported by e.g. Berry and Westfall (2015) and their encouragement to use technology instead of prohibiting it. Saritas (2015) also stated that technical based solutions possess the best potential to succeed with an enhancement of learning in the digital nature of today's school.

IoT opens up for many opportunities and research shows that its potential to manage school challenges in an effective way is large (Saritas, 2015; Moreira et al, 2017). Situations that are currently seen to have a great opportunity to be managed with IoT-interventions are mentioned by Moreira et al. (2017) to be higher education-objectives such as building automation or energy management. The use of IoT in pre-university education fields, as in upper secondary school, is more challenging and lacks a proper research base, leaving it with a lot remaining to be done (Moreira, 2017). Exploring how learning can be enhanced in today's digital environment with the help from IoT- interventions therefore brings a valuable research contribution when focusing on an upper secondary school-level in this study. Examples of different research about IoT in school are presented below, where the representation from higher educations can be noted.

A study performed in Colombia by Gómez et al. (2013) shows how IoT could be implemented in school settings. They attempted to enhance learning with IoT in an introduction to systems engineering-course, during one term in the University of Córdoba. The learning objectives for the students were related to hardware of computer systems, to know the components functions and interaction between them. The components that the students were intended to learn about were laid out with a NFC-tag connected to them as well as a QR-code which allowed students to interact with the physical objects. The interaction led to a graphical user interface in their smartphone, which contained information in the form of animations, text or audio. Followed by the provided information were activities for the student to do, in order to enhance their learning. The evaluation of the system was in regards to the previous IoT-less teaching environment being used as a control group. The students in both the experimental and control group had to take a pretest and a post-experimental test.

The results showed an increased knowledge in the experimental group. Gómez et al. (2013) concluded that Internet of Things improves student's academic performance. They ended on the note that Internet of Things in education is in its initial stages, which implies that there was a lot to be done in 2013. This indicates that even if the subject was rather undiscovered, the increment in academic performance was present and that IoT could be used in order to enhance learning. Using IoT to provide learning-information to students in an interesting and different way, could allow for the students to get excited about it and hence absorb the knowledge to a better level than without IoT. This was proved by Gómez et al. (2013) as the experimental group performed better than the control group in the evaluating test. Even if this example shows IoT's positive impact on learning, the used IoT-devices (NFC-tags and QR-codes) are of a rather administrative nature as they simply directed the students to the user interface. The interaction is there, but the data collection and combination that could result in valuable outputs are not. It could be possible to integrate data mining-actions (data collecting and data combination) to the graphical user interface, using these actions to collect data about different happenings in the student's behavior and performance and extract a valuable outcome from that.

Another study, performed by Ali et al. (2017) investigated the usage of IoT in school and exemplified how IoT could enhance learning. The study used IoT in combination with case-based learning in medical education. Case-based learning has been an effective tool for students in the medical field to get practical knowledge. However, it is often used without a "flipped learning" methodology, which is a methodology that enables teachers to provide instructions online, outside of class. Ali et al. (2017) proposed an IoT-based Flipped Learning Platform with the functionality to gather data from patients that had agreed to participate, exists sensors such as wearable health monitoring sensors. The teacher could then use this information to set up real cases that the students were to solve. The data collected with IoT-devices could provide sufficient information to realistically mirror a real-life case. Feedback was given to the student from the teacher, based on their actions in regard to the case. Ali et al. (2017) stated that the satisfaction level was at 70%, based on their prototype. They suggested that their IoT-based solution could be adapted to other educational domains as well. This showed that IoT is a steppingstone for opening up many new interventions that were not previously possible and that it can be used as a part of the learning itself rather than a way of optimizing the school environment. The study by Ali et al. (2017) shows a less administrative way of using IoT as the Flipped Learning Platform uses constant data collection and interaction to provide with an output that could function as a mirror to a real-life case. Also, the interacting function between the system, the student and the teacher shows how IoT can function in a beneficial way. The constant interaction and data collecting provide with valuable assistance for both the student and the teacher, which in turn could enhance learning.

Retaining student's focus during a class is considered to be problematic according to Uzelac, Gligoric & Krco (2015). They performed a study, investigating how different physical parameters affect student's focus. The participants were university students at the age of 18-20. To measure the examined parameters, the study used different IoT-devices that enabled the collection of data by different sorts of sensors. The measured parameters were noise level, CO2-level, air-humidity, temperature and air pressure. Determining the students' focus was done by letting the students respond during class if they felt focused or not by pressing one of two buttons (yes/no) via a web page. Comparing the measured parameters with the student's responses resulted in three parameters that significantly affected the focus. These parameters were CO2-level, noise and the combination of temperature and humidity. Uzelac et al. (2015) suggested that IoT-devices can be used in real time to determine whether the classroom is optimized for the student to focus in or not and in that way assist the teacher with information on how to lecture. It was also mentioned by Uzelac et al. (2015) that IoT-devices that register eye-movement could work as a focus registrator instead of the student's current real-time feedback. The study shows that keeping focus is a problematic aspect for students and that it is possible to increase the student's ability to maintain focus during class with the help of IoT. The study also shows that IoT has a lot of potentials to collect different valuable data in different ways.

1.5 Delimitations

The base of this study was formed by qualitative data collected from upper secondary school teachers in Stockholm, Sweden. The teachers work in a school of technical nature and teachers from other schools without the same technical nature and advantage were not included in this study. The working process and final contribution of this study focused on circumstances brought by the current digitalization and does not focus on solving administrative tasks that could be argued to enhance learning, such as attendance documentation or similar.

This study did not take into consideration any practical boundaries or accessibility difficulties for the generated intervention. The theoretical and empirical ground was sufficient as support for this. This resulted in a low fidelity prototype. Even so, this was considered to be valuable for this particular study. This study did not take students direct opinion into consideration and relied on the teacher's expertise to represent the educational aspect.

1.6 Summary of theoretical background

Today's school is transforming in line with the ongoing digitalization in society. The transformation leads to altered circumstances and arose challenges that require technological interventions to adjust in an effective way. Challenges that could be affected by digitalization are for instance *focus* and *motivation*, which has been proven to have an effect on learning. To manage these challenges is of importance to the enhancement of learning. IoT possesses a large potential to deal with challenges in school, but research is lacking on how to use it in education pre university.

2 Research method

2.1 Research strategy

Conducting this study required a mix of empirical and theoretical information in order to answer the research question and accomplish the aim. Several strategies could help this study to succeed, with different courses of action.

Design based research (DBR) is a research approach that can be characterized by having the potential to incorporate educational practice with its theory (Bakker & van Eerde, 2015). This leads to an ability to generate relevant interventions to complex educational problems, alongside with scientific insights regarding these generated interventions (Bakker & van Eerde, 2015). It is further mentioned by Pool & Laubscher (2016) that a DBR should result in a clarification to problems of teachers and learners, and ideally also provide with created and adopted solutions to the problems, which is in line with this study's aim. Continuing, Pool & Laubscher (2016) states that there are two main outputs to expect from a DBR, namely: *design principles* and/or *innovative interventions*.

The literature agrees that several phases should be included in a DBR, without any specific definition of how these phases should be designed (Pool & Laubscher, 2016). The power to modify the phases throughout the study provides means to quickly adapt to new circumstances that may occur. Adopting DBR to a short-term project, such as a Masters or Ph.D. dissertation, has initially been criticized in the literature, but Pool & Laubscher (2016) argues that the approach is relevant to short-term projects as well. As long as at least one of the principal outcomes, *created design principles* and/or *empirically underpinned interventions*, are achieved through a number of phases and iterations, a DBR-application could be valid for short-term projects as well. Applying DBR to a short-term project differentiates in the aspect of time in comparison to bigger projects. Pool & Laubscher (2016) argues that what mainly is gone missing when applying DBR to short-term projects are the number of iterations, which leads to a less refined and less effective process.

A possibility to conduct a short-term DBR-project based on micro- and meso-cycles was suggested by Pool & Laubscher (2016) and proved to be successful. The framework from Pool & Laubscher (2016) was built and developed from a general DBR-approach presented by Reeves (2006) and also from a suggested implementation of micro- and meso-cycles by McKenney & Reeves (2012). A fracture of Reeves (2006) DBR-approach suits the proportions of this study and is shown in figure 1. It shows an underlying expected progression for a DBR and also how the overall proceedings in this study were developed.

Figure 1. General design based research-approach (Reeves, 2006).

From the DBR-approach shown in figure 1 and a framework by McKenney & Reeves (2012) using micro- and meso-cycles to represent the different phases in the process, a model was developed on how to perform a DBR in short-term studies (Pool & Laubscher, 2016). The micro- and meso-cycles are illustrated in figure 2 to ease the understanding of their appearance. One micro-cycle represents a smaller phase carried through. Meso-cycles could be represented with a set of micro-cycles and is basically a larger phase or a set of smaller phases carried through. Figure 2 also shows a macro-cycle, which only represents the entire DBR-process. The varying sizes of the cycles in figure 2 merely illustrate that each cycle possesses its own extensiveness

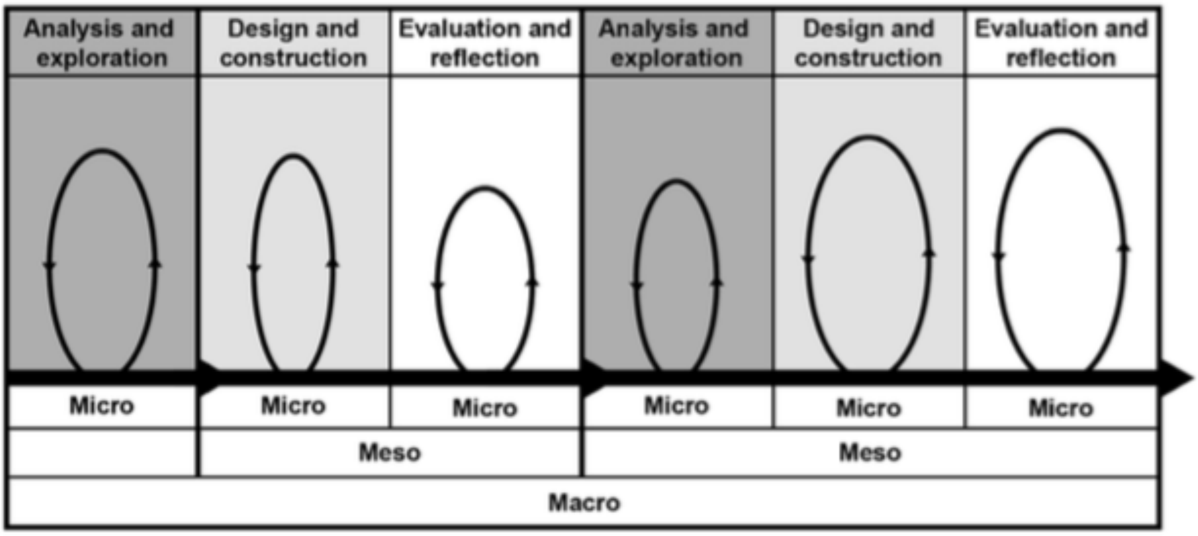


Figure 2. Cycles in the DBR-process (McKenney & Reeves, 2012).

This study had the intention to be conducted within the guidelines of DBR and from a suggested model suggested by Pool & Laubscher (2016). Working in line with this model was considered to be relevant when working on short-term projects, with support from Pool & Laubscher (2016). To answer the research question of this study it is necessary to understand and clarify prominent problems as well as presenting a proposed solution. This was considered to be in accordance with what was mentioned in the literature to be the features of DBR (e.g. in Pool & Laubscher, 2016; McKenney & Reeves, 2012).

Randomized control trials (RCT) is a commonly used research strategy (Bakker & van Eerde, 2015). It is based on providing one group with the new intervention and another group to go through the process as it is currently. Since this study is of exploring nature and will not be able to test the resulting prototype due to time and resource limitations, this research strategy fails in that aspect. There are other certain problems with RCT in regards to education. One of such issues is the lack of suitable answers to the question “why and when does it work?” (Bakker & van Eerde, 2015). Another problem emerges with the limitation of generalization. RCT uses random sampling to represent a generalized population, which seldom is plausible in educational research (Bakker & van Eerde, 2015). Implementing RCT to this study would have been problematic due to the need of having an intervention in an early stage and testing it to conclude its effectiveness. That would not fulfill the aim of this study and it would instead measure something that was already ready for practical tests. With DBR, it is instead possible to test as well as redesign the interventions based on theoretical and empirical aspects during the process and its iterations, which is considered as beneficial in this study.

Another research strategy frequently used in social sciences is action research (Majgaard, Misfeldt and Nielsen, 2011). Action research has been described as “social engineering” with the result of changing social structures while empowering the participants in the process (Majgaard, et al, 2011). It is an iterative process that will provide new understanding, not only to the researcher but to the participants as well. They have an opportunity to have a real impact on the design part of the intervention, which should be visible in the final design. Bakker and van Eerde (2015) mentioned that there are similarities between action research and design-based research. The research methods are both open, interventionist and with multiple iterations. However, action research focuses more on the "action" while design-based research uses more theory as a basis. This difference in focus sets design-based research ahead as the research method in order to answer the research question in an appropriate manner.

2.2 Data collection method

Collecting qualitative data of value for this study requires expert opinions from participants involved in the requested environment, which can be gathered in different ways. The collected data will contribute to develop and evaluate a suitable prototype. Data will consequently be collected on several occasions during the study.

Semi-structured interviews
A necessity of speaking freely about current issues was considered to be important in order to gather data that is thought through and reflected upon. Conducting semi-structured interviews provides with feelings, thoughts and reasonings formulated in depth, which allows the interviewer to gain an in-depth understanding of the subject in question, unlike e.g. questionnaires (Denscombe, 2014). Predetermined questions and subjects to be addressed in the interview should exist. The interviewer is however prepared and welcomes a change in question-order and encourage the interviewee to develop answers in a free manner and speak widely about the given subject. Semi-structured interviews are considered to be time-consuming, which implicates that a small number of interviewees are recommended to participate in each session (Denscombe, 2014). That could bring a slight subjectivity to the collected data, which could result in the data being considered as non-representative.

The possibility to argue and discuss was considered to be of value for this study when collecting data about current challenges and possible solutions. In semi-structured interviews, the arguments and discussions merely occur between interviewer-interviewee and lack interaction between the participants, which is possible in focus groups. Interviews can provide with the opportunity to fully describe complex phenomenon before extracting the data, which makes for a very useful tool when for instance evaluating this study's developed prototype. Kumar (2011) also states that interviews enable for gathering in-depth opinions while also being able to explain questions that might have been misinterpreted by the interviewee, something that also is of value for this study when evaluating the prototype. Sending out a questionnaire to evaluate the prototype would not provide the same assurance that the respondent understands the questions and their intention, and an in-depth explanation of opinions from the respondents would be difficult to capture.

Focus groups
In order to widen the perspective of the collection of data, *focus group* is a method that could be seen as an expanded version of unstructured or semi-structured interviews. Focus groups involve a group of participants, encouraged to get involved in a discussion that is controlled by a moderator. The moderator is responsible to lead the focus group session and facilitate group interaction by creating a comfortable discussion atmosphere, keeping the discussion to the actual topic and to encourage participation from all participants (Denscombe, 2014). The moderator-role can be divided into several persons in order to ease the responsibilities, such as keeping notes while listening to the reasonings. Audio recordings are suggested by Denscombe (2014) to capture correct interpretations and citations

from the collected data. The interaction in a focus group is mainly between the participants, where the moderator only steps in to preserve the intended focus. Focus groups also encourage reflecting and thinking individually before the interaction. This interaction is of great value for the problem understanding and the solution finding in this study and is something that is not possible with e.g. personal interviews. Group interviews could also have been a possible method to use in this study. Kumar (2011) mentions that the major difference between group interviews and focus groups are the issues being discussed, which are more specific when conducting focus groups. Focus groups, as opposed to other methods, is less costly and more time efficient (Kumar, 2011) which makes it an attractive choice in this study and generally for smaller-scale studies.

Discussion

The features of the focus group methodology are something that was considered to be well suited for the purpose of this study, where the initial need of problem identification and further prototype design can benefit from an interaction between participants in a focus group session. The open discussion environment and the wide opinion base from several participants contribute with valuable data to this study. Features of a semi-structured interview were of interest as well in this study, foremost to the final phase of the study to evaluate the prototype. In several DBR-studies, focus groups have been used as a method for data collection to help to develop a prototype, with success (e.g. in Pool & Laubscher, 2016; Schmitz et al, 2015) and is also concluded to contribute on achieving fundamental design research goals when refining design artifacts (Trembly, Hevner and Berndt, 2010). Focus groups were used in the initial stages of the study in order to provide documentation of challenges and probable IoT-functions for the prototype. The evaluation of the prototype was performed by the means of an expert opinion collected through a semi-structured interview.

2.3 Participants

The sampling in this study is by exploratory nature. Denscombe (2014) describes exploratory samples being suitable for small-scale research with their functionality to provide the researcher with sufficient means to lead to discovery. It is not as important to get a proper representation of the population as it is with representative sampling; hence it is often referred to with qualitative data. Quota sampling is done by first establishing requirements for the sampling to include which ones are described as categories and then it is up to the researcher to fill the quotas by any means. It could be by choosing the first one available until each category is sufficiently filled (Denscombe, 2014). Quota sampling results in less data collector errors as opposed to availability sampling where participants are chosen based on convenience, however, it does also require greater resources (Daniel, 2012).

Another possible sampling method is purposive sampling where the sample is handpicked by the researcher. The method is based on the researcher having sufficient knowledge in order to identify which samples will provide the most valuable data. This sort of sampling is referred to as being well suited for exploratory samples (Denscombe, 2014). However, the authors of this study do not have enough knowledge to properly assess key sample targets. It requires more effort as well as greater resources such as time and money and with up to date information (Daniel, 2012). This makes it less appealing for a small-scale study, thus the sampling method will be quota sampling. The quota sampling will be done by first assessing requirements for the participants. The first category in which all participants must fill is that their primary profession must be as a teacher. Furthermore, all the participants would have to cover at least three different subjects as a group.

An upper secondary school with a technological and innovative orientation was chosen to collaborate within the conduction of this study. The participants were teachers, sampled from that school using quota sampling. Teachers have a close proximity to learning and a mix of hands-off experience as well as pedagogical expertise from education. Therefore teachers have an advantage in finding suitable interventions that will have a direct impact on learning. The teachers were picked based on convenience after they filled the categories required. The input from teachers as a data collection source will contribute in a large extent to the findings of this study.

2.4 Data analysis method

The analysis of the gathered data is required to handle qualitative data, in the form of audio recordings and written notes. The expected outcome from the data analysis in this study is intended to bring understanding to the subject and its problems/challenges, but also to provide with constructive feedback for the development of a prototype.

Conducting an adequate analysis of audio recordings requires transcription of the file(s), in order to simplify detailed searches and data comparisons (Denscombe, 2014). Content analysis is a qualitative data analysis method capable of handling any kinds of text and is used to quantify the contexts in a text (Denscombe, 2014). Content analysis provides a valid and reliable interpretation of collected qualitative data that can be used with relevance in scientific matters (Moretti et al, 2011). The ground idea of this analysis method is to form categories from the collected data and use the frequency of these categories to provide a concrete representation of the most valuable parts in the data. Moretti et al. (2011) used content analysis to analyze data collected from focus groups in a successful way. There is although some uncertainties and doubts about the procedure in content analysis. The risk of research-bias from the subjective way of forming categories and interpreting the data was for instance mentioned by Moretti et al. (2011) as one aspect of uncertainty. Qualitative data often comes with a lot of value, different angles and with a vast amount of information, which implicates a difficulty in the analysis. Content analysis could nonetheless be considered to handle qualitative data analysis well by converting this kind of raw data into valid and concrete interpretations, even if the risk of research bias exists.

Denscombe (2014) presented a relatively straightforward step-by-step procedure for content analysis (p. 282):

1. Choose an appropriate sample of text
2. Break the text down to smaller component units
3. Develop relevant categories for analyzing the data
4. Code the units in line with the categories
5. Count the frequency with which these units occur
6. Analyze the text in terms of the frequency of the units and their relationship with other units

The analysis provides clarity to what the data is representing. A high frequency could indicate which category catches most attention in the focus group-discussions and also what engages the participants. If a category would have an aspect that is groundbreaking or abnormal it could lead to engaging a discussion and hence add frequency. In a similar way, the frequency could stay low if the category would not engage at all. The categories and their frequency therefore indicated what was considered as important and valuable from the participants.

2.5 Research structure

The chosen research strategy, suggested by Pool & Laubscher (2016) and originated from McKenney & Reeves (2012) and Reeves (2006) was modified and customized to fit the characteristics of this study (see figure 3). The term "cycle" that was used by Pool & Laubscher (2016) and McKenney & Reeves (2012) was substituted in this strategy to the term "phase" to better illustrate the differences between the phases of the process.

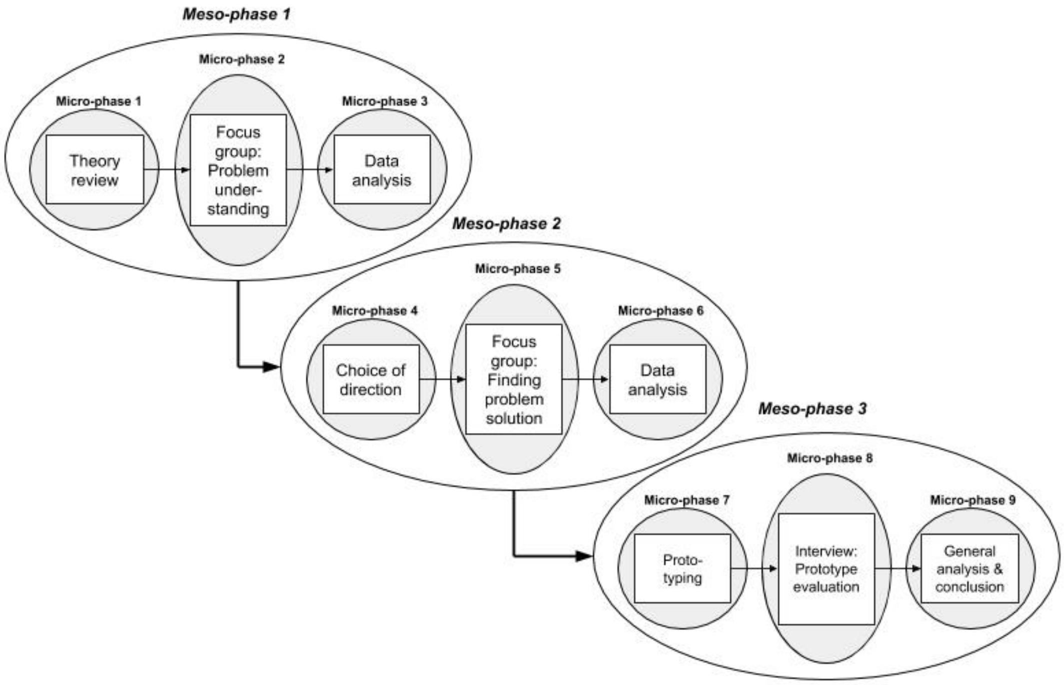


Figure 3. A visualization of the customized research strategy for this study.

This study was divided into three meso-phases where the underlying structure is similar to each other, but where the purpose and output differs. The first meso-phase was intended to extract a general understanding about the area by a thorough theoretical review, a focus group to gather a perspective from teachers and an analysis that summarizes and gathers crucial and relevant aspects from the collected data. Having a base of relevant and concrete information about the problem situation led to the next step, which was to find out how the problem situation could and should be handled with help from IoT. Meso-phase 2 represents this next step and it was initiated with a choice of direction by the authors. In order to keep the study's path within reasonable limitations, the authors chose to carry through with one specific problematic (challenge) gathered from meso-phase 1. In the second focus group (micro-phase 5), a possible solution was searched for the chosen problematic.

In meso-phase 3, the focus lied on evaluating the developed prototype that had been formed from the gathered data in meso-phase 2. Expertise from people with knowledge in the area provided with opinions and reactions about the prototype in order to find out the potential of it. These opinions and reflections provided with important inputs and aspects for this study to use for the final discussion and conclusion.

2.6 Research ethics

This study is performed in accordance with good research practice described by the Swedish research council (2011). The participants of this study were not exposed to any risks by participating in the conducted focus groups or interview. Before accepting to participate in the focus group or interview, it was cleared that audio was going to be recorded and that the participants were going to be anonymous in the study. Additionally, an informed consent form containing all of the relevant circumstances for the participants was handed out and signed by the participants after accepting the terms. To see the entire consent form, see Appendix A. All of the participants accepted the participation in the study after reading the consent form and understanding the terms.

This study only included upper secondary school teachers in the population and did hence not involve any vulnerable populations.

No minors were included in this study. It was a possibility to involve students, including minors, in this study but focus was laid on the teacher's perspective.

No personal or confidential data was gathered in the data collection except for their profession.

No form of financial compensation was offered and the voluntary participation was mentioned orally and in the consent form.

The collected data was in the form of audio recordings and handwritten notes, which were stored under the supervision of the authors. The audio-recorded files were erased from the used dictaphones directly after transferring the files to one of the author's personal computer. The handwritten notes were also kept under one of the author's supervision. Both the audio files and written notes were transcribed into digital form into one of the author's personal computer. The data was shared only between the authors, the author's supervisor and a researcher conducting a study related to this one. All this occurred with the participant's consent. The data provided by the participants will be kept during one year from the date of collection, and will then erased.

2.7 Research quality

With the qualitative nature of this study, the quality of the results was assessed according to the terms of *credibility* and *confirmability,* mentioned and suggested by Cope (2014). The *credibility* tells about the data and its truthfulness and also about how the data is interpreted and represented in the study. When it comes to the term of *confirmability*, it tells about how the collected data is demonstrated and how well it represents the actual responses from the participants, with as little bias as possible from the authors.

3 Findings

Chapter 3 presents all the relevant findings of this study in a structured way according to the chosen research strategy and its structure, as shown in figure 3. Each phase is presented in separate subsections. Each meso-phase includes three micro-phases. The initiating meso-phase had a purpose of analysis and exploration of the area. It also collected valuable opinions and reflections from teachers to the considered matter, which is IoT in today's school. Meso-phase 2 intended to find a solution to the found problematic. Finally, meso-phase 3 evaluated the proposed intervention and determined its potential.

3.1 Meso-phase 1: Problem understanding

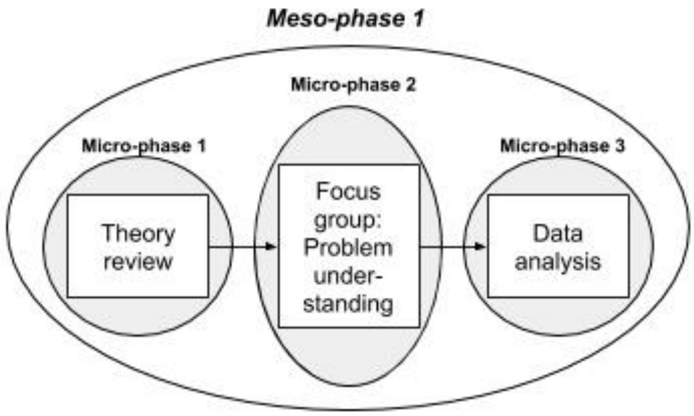


Figure 4. Overview of meso-phase 1 and its structure with micro-phases 1-3. A fraction from the general research structure presented in figure 3.

3.1.1 Micro-phase 1: Theory review

This first micro-phase was designated for theoretical review and was done to fully grasp the current development in the field of IoT in school and to assess potential possibilities and constraints. This review contributed with the necessary preparation for upcoming events during the entire process. Micro-phase 1 provided with both general knowledge and information, but also with a firm ground for the planning of the focus group that took place in micro-phase 2.

The theory review provided with knowledge about the development in the field of IoT in school and to assess potential possibilities and constraints for the study. This was done mainly by reviewing peer-reviewed scientific articles but also through information from other articles and case reports. Key findings collected from the theory review are presented below:

- IoT has an enormous potential in all fields in society and that the usage of IoT is growing intensively.
- In the area of education, IoT is used mostly in higher education levels.
- When it comes to the usage of IoT in pre-university education levels (from upper secondary school and lower) the literature showed a lack of research contributions.
- Digitalization affects the circumstances in most social environments, including school, leading to emerged challenges

- Emerged challenges in school need to be managed in appropriate ways in order to enhance learning
- Focus and motivation has an impact on learning

Due to these findings, this study focused on circumstances and perspectives from pre-university education levels. Contact was made with an upper secondary school in Stockholm, Sweden, to cooperate with and to function as participants in the conduction of this study.

Wanting to use IoT primarily to enhance learning and to also avoid the complexity in involving minors (students) led to only using active teachers as participants in this study. The authors also concluded that the challenges, expected to be collected from the teachers, should not be in an administrative matter. An example of such administrative matter could be *logging student attendance.* The searched challenges should instead be something that has arisen from digitalization and where an IoT-intervention could be used with the main intention to enhance learning. Another result from the theory review was to have an open mind for the upcoming intervention (prototype), meaning that importance should be held on the intervention's functionality and its potential to enhance learning, not on the possibility of technically and practically produce a fully working prototype in this study.

3.1.2 Micro-phase 2: Focus group

With the outcome from micro-phase 1, the preparations for the first focus group were initiated. As a first opportunity to collect data from teachers, the overall intention was to collect opinions and reflections from the participating teachers about challenges and overall problematic that currently exists in school and that had arisen from digitalization.

The setup of the workshop was that five teachers with different teaching areas participated. Six teachers were requested but due to the difficulty in finding a matching time between six already busy schedules, five teachers were considered as enough. Table 1 shows details about the focus group that was held. The different teaching areas of the participants whereas following: two Swedish/ English-teachers, one computer science-teacher, one biology-teacher and one mathematics-teacher.

Table 1. Details about the first focus group.

Focus group 1 – Problem understanding					
Participants	Duration	Time	Date	Location	Tools
5	~60 min	13:30	5th Feb, 2019	Stockholm	Notebook, post-its, dictaphone

Before the focus group, the authors formulated a question that the focus group was intended to answer:

> *What challenges exist in today's school, that could affect learning and that have been affected by the ongoing digitalization?*

The authors acted moderators in this first focus group and the entire meeting was audio-recorded. The focus group started with a short oral presentation about the ongoing study, along with a handout of notebooks and a bundle of post-its to each participating teacher. Also, a consent form was handed out to each teacher who was asked to sign it if they agreed on the terms. The consent form can be seen in Appendix A. After the short introduction and having ensured that the teachers had understood the content and purpose with the focus group, the first task commenced. In this first task, the teachers were instructed to silently and individually reflect and write down on post-its; current challenges in school that have arisen from digitalization. After five minutes of the individual reflection, the written post-its were collected by the moderators and put up on the wall for everyone to see. Each teacher was given the opportunity to explain what they had written down and the rest were welcomed to start a discussion. This engaged all five teachers and the discussion lasted up to 30 minutes. To end the focus group, the teachers were free to add something or ask questions and a general discussion took place for around 10 minutes. After this, the focus group was ended.

3.1.3 Micro-phase 3: Data analysis

The layout of the focus group was intended to contribute with an understanding of the existing challenges that teachers are experiencing and facing in today's school. The open-minded and free discussion gave the teachers an opportunity to speak freely and to not force opinions in order to contribute to the discussion.

The participants in this focus group will from now on be referred to with their teaching areas in the text. Since there were two Swedish/English teachers they are referred to with a complementing number. All citations from focus group participants are translated from Swedish to English by the authors of this study.

Different categories were set in order to start the coding on the transcribed material. The categories were determined from the post-its that the teachers had written their challenges on. Five different categories were set, where all of them represented a challenge or a challenge-area that had appeared on the post-its. These five categories are presented in table 2 along with their counted frequency.

Table 2. The challenges as categories, developed from the teacher's discussions.

Category	Challenge explanation	Frequency
Focus	It is difficult for students to keep focus during longer periods. Mostly due to notifications on their smartphone or other distractions from technology.	**11**
Technology dependency	Students are many times unable to preform tasks without technology, e.g. difficulty in spelling correctly without spelling aid (autocorrect).	**8**
Shortcuts	Taking shortcuts is not always good, especially when it comes to learning. Instead of testing and failing and learning from that, students rather use e.g. search engines to find answers directly.	**6**
Information overload	Students and teachers find it difficult to handle the substantial amount of information and sources from the internet.	**5**
Others	Challenges that were brought up but don't have a clear relation to digitalization as a source. For example that it is hard for students to find motivation to start their school tasks, and it is hard to give individual feedback to 30+ students.	**4**

The frequency was counted whenever a category was mentioned with the intention to address it as a challenge in school. During the focus group, teachers tended to address challenges that were not directly caused by digitalization but still were existing challenges. These challenges were categorized into one mutual category named "*Others*" and were not excluded in the analysis, as they in fact are existing challenges.

The category "Focus" was the most frequent category in the analyzed material consisting of the transcription from the total approximate 40 minutes of active discussion during the first focus group. This category was agreed to be a challenge from all the participating teachers. **Swedish/ English-teacher 1** formulated the challenge of focus as follows:

> *"I feel like distractions or focus loss is a huge problem. When they (students) rather start doing other things, for example on their phones, than what they actually should do." (Swedish/English-teacher 1, personal communication, Feb 5, 2019)*

The collected opinion about the impact that focus has on learning is in accordance with the studies of Egong (2014), Uzelac et al. (2015) and Jacobsen & Forste (2011).

The distraction from different notifications or the fear of missing out happenings on social media, and on the Internet overall, was explained as eventual reasons for the difficulty in keeping focus. **Swedish/English-teacher 2** formulated it in the following way:

> *"I believe Internet, and mainly social media, is the main distraction in class today" (Swedish/English-teacher 2, personal communication, Feb 5, 2019)*

Another challenge that was identified was that students tend to be dependent on technology when solving problems or doing tasks. This challenge is represented by the category "Technology dependency" shown in table 2. It was stated by the teachers that if technology would fail or disappear, students would have problems when handling every-day tasks. An example was brought up that in present time, students are dependent by technology in order to spell correctly (spelling-programs or autocorrect-functions). The **mathematics-teacher** expressed it as follows:

> *"I am worried about my students not knowing how to spell properly without using autocorrect." (Mathematics-teacher, personal communication, Feb 5, 2019)*

The category referred to as "Shortcuts" was explained by the teachers as technology allowing students to skip the learning part in a task and go straight to the answer. Easy access to information and a large amount of different information available on the Internet can many times be of great value, but not when it comes to using it as shortcuts in certain learning activities. A short fraction of a dialogue between **Swedish/English-teacher 1** and **Swedish/English-teacher 2** presents the challenge as follows:

> *"Shortcuts are more likely a problem and not something that the students can learn from. But they (students) usually take the easy way out without learning anything" (Swedish/English-teacher 1, personal communication, Feb 5, 2019)*
>
> *"You mean like copy-paste?" (Swedish/English-teacher 2, personal communication, Feb 5, 2019)*
>
> *"Yes, in a way. It doesn't have to be that specifically but definitely in that sort of way." (Swedish/English-teacher 1, personal communication, Feb 5, 2019)*

The collected opinions about the influence that social media has on focus, the technology dependency and the shortcuts could all be seen as a consequence of digitalization. The effect that the digitalization has on society is in accordance with the studies of Dufva & Dufva (2018), Saritas (2015) and Mårell-Olsson & Bergström (2018)

With a large amount of information available through the Internet, it is hard to determine what information is relevant or even true. This yields for both students and teachers and in the focus group the teachers also mentioned that information overload also applies to curriculums. An increasing amount of information makes it difficult for the teachers to plan and determine what should be included in the courses.

Several different challenges with different origins and certain similarities appeared during the focus group. Some challenges were not involved as much as others in the discussion, nevertheless, they were mentioned to be existing challenges in today's school. The category called "Others" represents these challenges that e.g. involve the students' motivation to start a school task or homework.

The overall outcome from meso-phase 1 was a possessed understanding of the provided challenges, where focus-keeping proved to be the most frequently mentioned challenge.

3.2 Meso-phase 2: Finding a solution

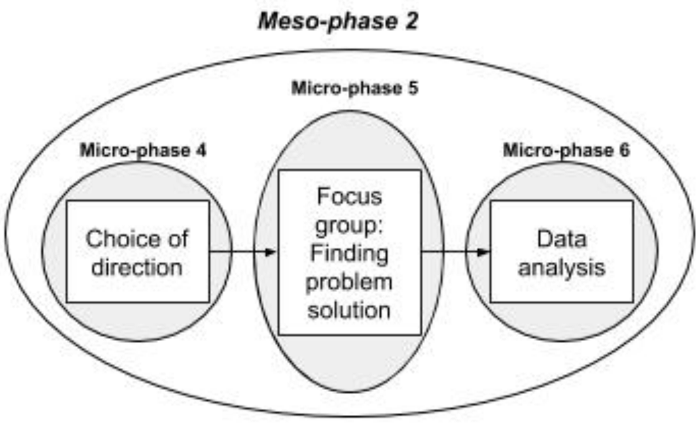


Figure 5. Overview of meso-phase 2 and its structure with micro-phases 4-6. A fraction from the general research structure presented in figure 3

3.2.1 Micro-phase 4: Choice of direction

The content analysis made in micro-phase 3 provided with visualization over the most frequently mentioned challenges in school. Five different categories with some differences covered a relatively large area of problematic. Finding a general solution or a solution for each category would have required a lot more resources and time than what was available for this study. With that reason and to keep the solution as narrow and specific as possible, a decision based from the content analysis was made to proceed with the category "*Focus*" and to find an IoT-solution for that particular category (challenge). The identified challenges from the first focus group are all existing and critical and could benefit from an innovative IoT-based solution. This choice of direction, to proceed with *focus*, determined the setup for the second focus group.

3.2.2 Micro-phase 5: Focus group

Planning the layup for the second focus group was now possible, having made the decision to narrow down the study and only proceed with the focus-challenge. The purpose of this focus group was to extract how IoT could be used to handle the challenge and help the students to keep focus during longer periods. All the ideas and thoughts were intended to come directly from the participating teachers, without any influence from the researchers who acted moderators in this focus group as well. The participating teachers were not the same persons as in the first focus group and all teachers had once again different teaching areas. The participants in this second focus group had following teaching areas: One mathematics/physics-teacher, one electronics-teacher, one Swedish/English-teacher, one gymnastics-teacher and the fifth participant was the school principal. Details about this focus group are presented in table 3. Six teachers were requested but, again, five teachers were accepted due to the difficulty of finding a matching time in the teacher's already busy schedule.

Table 3. Details about the second focus group.

Focus group 2 – Finding a solution					
Participants	Duration	Time	Date	Location	Tools
5	~45 min	14:00	2nd Apr, 2019	Stockholm	Large papers, whiteboard-markers, notebooks, dictaphone

Before the focus group, the authors formulated a question that the focus group was intended to answer:

> *What kind of IoT-based solutions could be implemented in school to manage with students focus loss, and in the end enhance learning?*

This second focus group was initiated with a presentation of the study since none of the participants was familiar with it previously. Papers with keywords were handed out for the participants to keep during the focus group as a reminder for the study's purpose. The keywords reflected the focus-challenge, the possibility of finding an IoT-intervention to handle it and the end goal to enhance learning. A short presentation for the term "IoT" followed, to make sure that the participating teachers possessed the same definition and understanding to IoT as the study. The teachers were all familiar with the term IoT but it was important to explain for the teachers that IoT does not only involve physical objects being connected, as the terminology "Internet of Things" could indicate. Due to the potential difference in perception about what IoT really is, this part of explaining to the teachers what is meant with IoT in the purpose of this study was critical. When performing this part of explaining IoT to the teachers, it was considered as valuable to have a brief discussion with the teachers and let them share their wonderings and insights. By that discussion, a consensus was in place and contributed to conform with the set definition of IoT in this study. The collection of data and the use of that data between interconnected devices was the essential part of the searched intervention that could handle the challenge. Having ensured that the participating teachers had understood the area, it was explained to them what was expected from them in this focus group, which was to share their opinions about what possible IoT-functions could be used to enhance learning. The focus-challenge was introduced and the participants were divided into two groups. The groups were equipped with a set of whiteboard-markers, a large piece of paper and notebooks. They were now told to freely discuss within the groups and to write down on the large paper, what kind of IoT-functions could be of success in order to help the students to withhold their focus during school tasks and in the end enhance learning. Before this begun, a discussion was initiated by the teachers about motivation being equally important as focus and that motivation and focus are connected to each other. Their persuasion led to the inclusion of the motivational aspect together with the focus aspect during the remaining of the focus group. Involving the motivational aspect modified the previously formulated question, determined for this particular focus group, by simply adding the *motivational* aspect to the already existing *focus* aspect.

The first moment consisting of small group discussions lasted for approximately 20 minutes and was followed with a general discussion including all the participants. The group's pieces of paper were shown and explained before this general discussion and the participants were then encouraged to intervene and commence a discussion about the suggested functions, ideas or interventions. This ending discussion lasted for approximately 15 minutes before the time had run out. During both discussing-moments, the moderators did not interfere with any opinions or guidelines.

3.2.3 Micro-phase 6: Data analysis

To collect teachers' thoughts and opinions about what kind of IoT-functions would help students to keep focus and to increase their motivation was the main purpose of the second focus group. IoT-functions were hence chosen as the element to be counted as categories in the content analysis. In the focus group-session, different IoT-functions were formulated in different ways without having to use the same terms. This complicated the analysis on when it is relevant to add frequency and not. Adding frequency as soon as a term is mentioned would not fill the purpose. Therefore, the authors made the analysis manually in a subjective way by adding frequency when an IoT-function was mentioned as a possible solution.

The frequency count of IoT-functions was made when similarity was noticed between proposed functions. These similarities were clustered into the categories that represent the different proposed IoT-functions that could work as solutions to the focus- and motivation-challenges. The categories were named in a rather abstract level, in order to simplify the clustering, and also to explain the suggested solution in a general way. Table 4 presents the different categories and the frequency, documented in the content analysis.

Table 4. The IoT-functions as categories, developed from the teacher's discussions.

Category	Category Explanation	Frequency
Assistance	Help the student to keep focus during a task, maybe with notifications. Step in and suggest different actions to retain focus. Learn what is disturbing to the individual student and adjust accordingly.	9
Self-perception	Visualize how the student is progressing with school tasks. in each subject. Showing both accomplished and pending tasks. Could also show active study time and other statistics for the student to see, and help to allocate time to study.	8
Interaction	Make it possible to share accomplishments with classmates. Could improve motivation to see other's accomplishments, but the sharing must be voluntary.	5
Avoid interruption	Make it possible to mute the phone when studying. Could be adjusted to the student's schedule.	3

The participants in this focus group will be referred to with their teaching areas in the text. All citations from focus group participants are translated from Swedish to English by the authors of this study. An important notice is that none of the participants in this second focus group participated in the first focus group. For instance, the Swedish/English-teacher in this second focus group is not the same as any of the Swedish/English-teachers referred to in the analysis of the first focus group.

An important aspect that was promoted by the participating teachers is that all students are different and they handle situations differently. Therefore it is important to not force them to do anything or make decisions for them to a high extent since the preferences will look different. Some students may need more breaks than others or some students may need longer time to properly finish an assignment, according to the teachers.

A function that was discussed and agreed upon was some sort of mute-function in the cell phone that would be activated when the student enters a classroom or when a school-task is about to be initiated. The **mathematics/physics-teacher** formulated it as follows:

> *"It would be great if their (students) phones were muted as soon as they enter the school or a classroom." (Mathematics/physics-teacher, personal communication, Apr 2, 2019)*

The discussion about the mute-function faded out as it was a bit too simple and the actual power of the function did not convince to be successful. It was discussed that it only would raise the eager to take up the cellphone due to fear of missing out. It is also already a default function in most smart-phones, to manually activate a silence-mode. The fact that notifications do disturb and interrupt student's focus was although still considered, which led into the discussion about using notifications to assist the student instead of disturbing. The suggestion from one of the groups was to assist the student to retain focus during a school-task with a sort of reminder or notification. In this aspect, it is important to learn about the behavior of individuals in order to avoid disturbances. If a notification with an intention to assist the student instead disturbs it, it will have an opposite effect. This function (category) was although the most frequent one in the content analysis and with the right settings, it was seen to have great potential. The **school principal** and the **electronics-teacher** indicated for the notifications being possible to use from the following dialogue:

> *"I think many people will benefit from having one thing at a time to focus on, and avoid being distracted or tempted to do something else" (Electronics-teacher, personal communication, Apr 2, 2019)*
>
> *"So, assistance to focus on one school-task and block other things out?" (School-principal, personal communication, Apr 2, 2019)*
>
> *"Yes and no, more of a reminder like in the top corner of the computer. Because that is something I have noticed, that some students need someone to sit next to them and telling them that 'this is what you are supposed to do'." (Electronics-teacher, personal communication, Apr 2, 2019)*

The suggestion to use notifications as assistance and not as a distraction is in accordance to the study made by Kallookaran & Robra-Rizzants (2017).

Another aspect that was frequently discussed was to visualize individual progress. Making it possible for the student to easily see its progress within the courses was agreed to have a good effect on the motivational matter. The **school-principal** formulated a suggestion of a progress-bar as follows:

> *"Today, it is hard to see what the student is doing, we don't have a system with that possibility. Now I only see a canvas, I would like to have a canvas for each course to see how far a student has progressed. And for the student to see by itself. Like a*

progress-bar, that doesn't have to show grades, but only if you have completed something and by that see your progression." (School-principal, personal communication, Apr 2, 2019)

The visualization could also show other facts such as statistics over the students studying time and how well the accomplishments have been at that time. This could, in turn, help the student to allocate time and schedule its studying occasions. The **mathematics/physics-teacher** mentioned for instance the statistics-aspect as following:

"What if some encouraging statistics would be possible to see, about students different achievements, performances, time spent on school-tasks? Seeing that would probably raise motivation with the student." (Mathematics/physics-teacher, personal communication, Apr 2, 2019)

The power of making it possible to see statistics and progress in school is in accordance with the study by Arens et al. (2015).

Related to this visualization-function is a function that was discussed as an interaction function. Similar to popular social media channels, some sort of sharing and posting accomplishments for others to see could have a value for increasing motivation. The **electronics-teacher** explained the proposed interaction as follows:

"If social media is so exciting for them (students) then I think that a similar function, but related to school-happenings. The students may find excitement in completing a task and share for their classmates to see." (Electronics-teacher, personal communication, Apr 2, 2019)

The functions that were put as categories for the analysis are presented in table 4, accompanied by an explanation and the frequency.

When listening to the discussion and later doing the content analysis, it was made clear that many times focus and motivation go hand in hand. The progress-bar and interaction functions could help the students to gather motivation and starting a school-task, as well as it could help them to keep focus for longer periods in order to achieve an accomplishment and see the progression clearly and maybe also share it and be proud of it. Being present in the discussions held in the focus group creates an understanding that may be difficult to possess from transcriptions and the content analysis. The rewritings about what was said about the functions are based on both the subjective experience from being present during the focus group combined with the help from the transcribed material and the content analysis. No direct quotations from the focus group-participants were included in this section, only rewritings and summaries of the overall intention.

The purpose of the focus group was considered as fulfilled since the collected opinions from the teachers and the discussion led to several interesting functions that could be developed and customized for the upcoming prototyping-section. The content analysis proved to become rather complicated due to the importance of context in the discussions. The frequency has great value to the result, but in this case, it is important to also understand the underlying meaning in the arguments in the discussions.

The overall outcome from meso-phase 2 was a possessed knowledge about which IoT-functions could work to maintain focus and raise motivation. Having the collected opinions from the participants as a base, it was now possible to start developing the prototype.

3.3 Meso-phase 3: Prototype

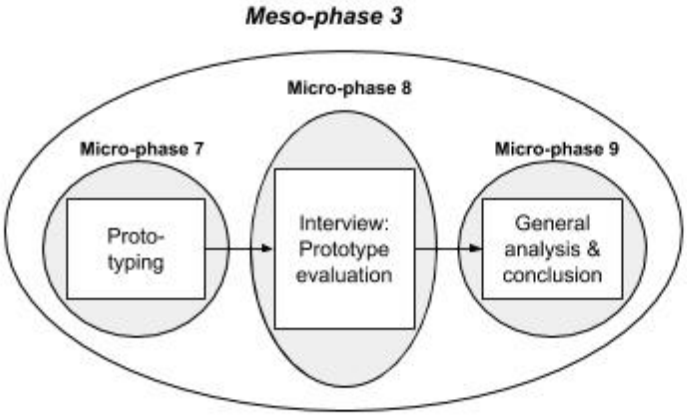


Figure 6. Overview of meso-phase 3 and its structure with micro-phases 7-9. A fraction from the general research structure presented in figure 3

3.3.1 Micro-phase 7: Prototyping

This section of *Prototyping* presents the development of the functions of the prototype as well as the characteristics of the functions in the prototype. How the resulting functions were developed is explained by using the proposed functions in table 4 as the origin and from that lead into the actual functions.

The course of the prototype was now possible to set, based on the analysis of both previous focus groups. Two major challenges are at the core of the prototype, being the identified challenges of *focus* and *motivation*. Focus was stressed immensely at the first focus group and it was considered to be an interesting aspect in the role of learning with the help of IoT. Focus has been shown to have an impact on learning in previous studies (Egong, 2014; Uzelac et al, 2015; Jacobsen & Forste, 2011). Motivation was only mentioned in slight regard to the other subjects in the first focus group. In the second focus group, the participating teachers set motivation on the same level of importance and relevance as the focus-aspect. The motivational aspect and its relation to learning are in accordance with the study made by Arens et al. (2015). The added motivational aspect was crucial for the prototype development and the authors decided that both the focus and motivational aspect should be dealt with. The prototype was hence developed with functions that interplay between *motivational* and *focus* purposes in order to enhance learning. All functions in the prototype were developed based on the recommended functions that were collected in the second focus group, shown in table 4, with support from theory.

The developed prototype was designed as a system for computers. The system and its functions are enabled due to the possibilities provided by IoT in the way of data collection and combination. This can be used as a communicating system in order to properly help the student in motivation- and focus-related matters.

The opening page in the suggested prototype that is the application named “Study mode” is shown in figure 7. All main functions are represented in some form in this figure and the upcoming function-explanations will occasionally refer to this illustration.

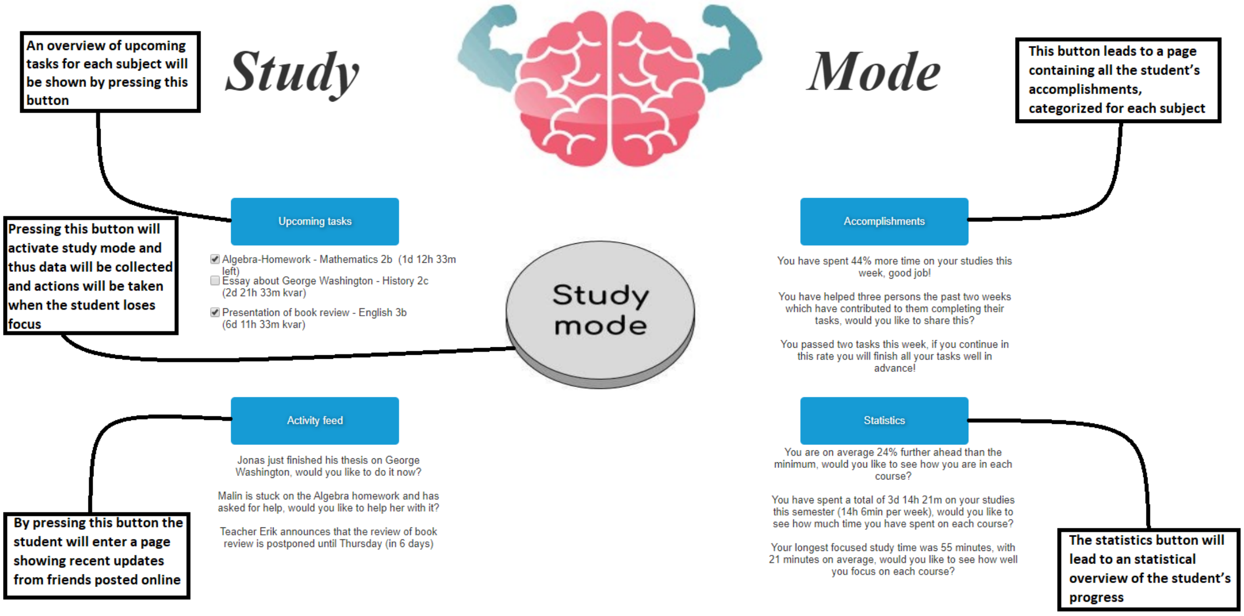


Figure 7. Mockup of the opening page in the suggested prototype, with its five core IoT-based functions.

Assistance

The difficulty of keeping focus for the students was stated by the teachers to be due to different kinds of reasons. Reasons for losing focus has existed for a long time in the school environment, but recently with the ongoing digitalization, the distraction mostly occurs from notifications and the easy access to entertainment through smartphones. The teachers that participated in the second focus group suggested some sort of assistance and guidance for students while doing a school-task, to help the student to keep focus during longer periods. The thought basis was to "fight fire with fire" and use notifications to help the student to stay focused during their study time of choice. Similar assistance with notifications was successfully done in the study by Kallookran & Robra-Rizzants (2017). The function was named ***"Study mode"*** and will be activated manually by the student. While active, different sorts of data will be collected regarding the student's behavior. This data will be used to help the student to maintain focus. In figure 7, the button in the middle, with the text "Study mode", represents the activate-button. When pressing that button the function is on, and the system starts its assistance for the student when needed to.

The data to be collected is about different happenings and behavior from the student. The purpose of this data collection is to detect inactivity and to suggest appropriate alternatives to restore the student's focus. This will be done by a system that learns the behavioral patterns of the student during study periods. With time, the accuracy of determining what in fact is inactive behavior and what is not will increase with the systems learning ability. The system will also learn to provide the students with effective alternatives based on the student's previous choices and behavior. Individuals act differently in different situations and by making it possible for the system to learn each student's individual behavior, this function will improve with time and possess valuable customization. Initially, the system will have set parameters that will change and adjust with time to properly fit the individual student. When suggesting appropriate alternatives for the student to restore focus, the system will measure the success of maintained focus and adjust it's suggestions accordingly to that. The system will hence only provide alternatives that help the student to stay focused and will not only rely on student's preferences. The data being collected is divided into four data-categories, shown in table 5.

Table 5. Data categories that planned to be collected in the focus-function.

Data	Explanation
Mouse activity	Data will be collected based on clicks, scrolls and the overall movement of the mouse.
Keyboard activity	Data will be collected based on key inputs by the frequency and combination of them.
Websites	Websites that are in no association with the subject will be a factor in assessing inactivity.
Programs	Programs that are in no association with the subject will be a factor in assessing inactivity.

The system will use inputs from all the categories in order to classify student activity or inactivity. An inactive mouse does not necessarily mean a loss of focus. However, inactivity could be the case if the inactive mouse is in combination with the student having an inappropriate website up without association to the subject. Furthermore, what might be classified as an inappropriate website could be within the purpose of study for the student. Facebook could be used for communication purposes between students. Thus, Facebook in combination with keyboard activity could classify as the students communicating, which should not alert the loss of focus-function. However, if the student uses the scroll to a vast extent, it could mean that the student is scrolling the activity flow, which then should activate the focus lost function. Another instance where multiple inputs could increase accuracy in assessing student inactivity is when games are involved. Mouse movement and clicks, in combination with frequent use of keys most seen in gaming settings like “w”, “a”, “s” and “d”, could result in a more accurate assessment whether the student is playing games or not. These are just a few of many examples of the interplay between data inputs that could be used to classify student inactivity.

When a loss of focus has been determined by the system, a notification will be sent to the student containing a suggestion of action with the purpose of retaining or restoring focus. The student will always have the choice to either accept or reject the proposed suggestion. These suggestions of actions can be formulated in different ways. The student can be suggested to change the color theme on the interface, call for a teacher or as figure 8 suggests: swap to a different assignment. It can also be to inform the student that a break is scheduled soon or show the progression of the current study session in order to increase morale. Assisting students and helping them to keep focus during longer periods directly impacts their potential of learning.

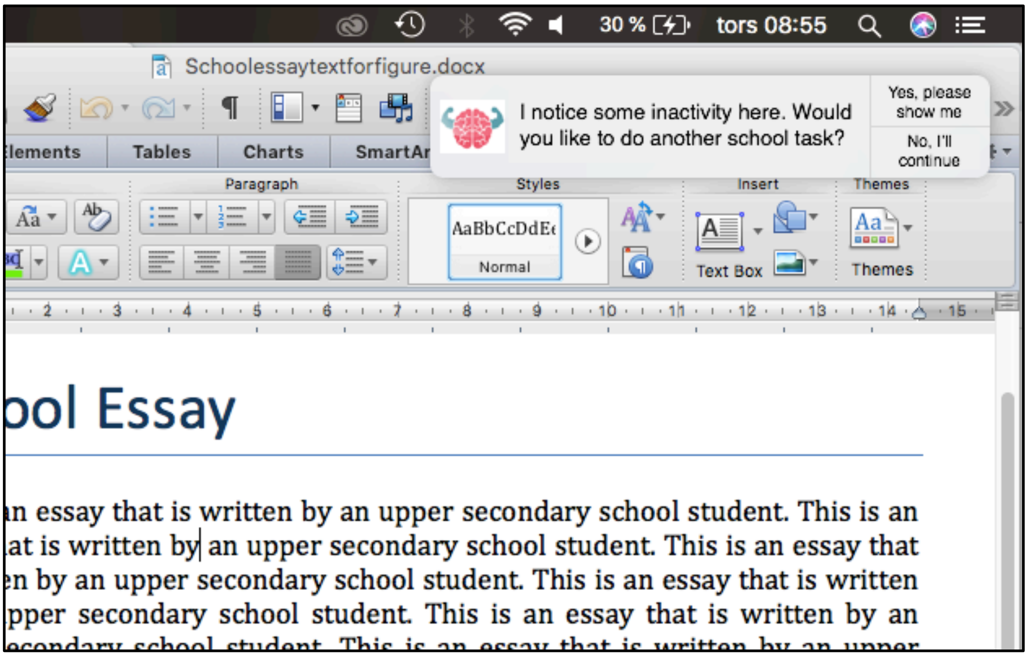


Figure 8. Example of a notification, in this case, being a suggestion to change school task.

Drawbacks of this function will be most apparent in the early stages of using the system. The system will initially use predetermined parameters that are not yet configured to the student's individual way of studying. Occasional wrongly determined inactivity-alerts will therefore occur initially, but with time the system will learn and the determination of activity will improve. The early faults will result in notifications that could disturb the student's focus, which in that case will be counterproductive to the system's actual quest to support the student. The risk of receiving notifications in an incorrect moment does exist whenever using the study mode but should decay with every use of the system. The danger for becoming an annoyance, like the infamous "Microsoft Clippy", is present and the frequency of notifications must therefore be to the more conserving side. A possibility for the student to decrease the frequency of notifications prevents that scenario from happening.

The relation between this function and IoT is the ability to collect different types data and by combining the data, it is possible for the system to find different patterns to assess whether the student is focused or not. The data collection and combination also contributes to allowing the system to learn from previous patterns and actions. With all the data collection, data combination and in this case interaction between the device and human IoT is considered to play a valuable part in this function.

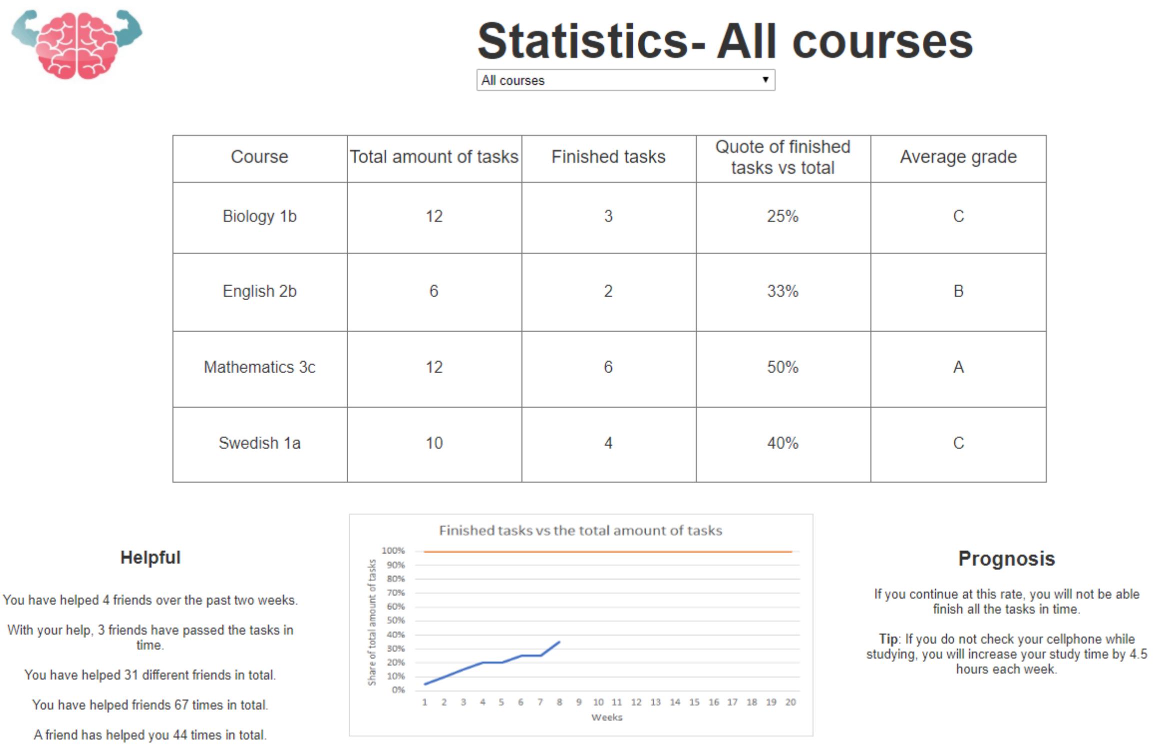
Self-perception

Motivation could be found through visualization of progression by sensing the approach towards an end goal. This is something that the teachers in the second focus group confirmed to be an important factor for students as well. The original idea of a progress-bar was divided into three subparts. Receipts of accomplishments formulated as boosts for the student to see in a direct and concrete way will encourage the student to keep performing and is one of the mentioned subparts. This function was named "***Accomplishments***" as presented in figure 7. In order to formulate appropriate accomplishments, different statistics were needed to be extracted and used as a basis. At the core of each accomplishment, the statistic will provide with values that reflect performance and give the accomplishment increased meaning. The opening page-view of this function named "***Statistics***" is visualized in figure 7, while figure 9 presents how the *Statistics*-subpage could look like with its different statistics provided. The possibility to see statistics about each course specifically exist in this *Statistics*-subpage, which was stated to be of importance by Arens et al. (2015) in order to impact study performance. The collected data, about student's study results and actions, can be used to extract several important statistics and be presented with an easy overview of the student's current state in the overall courses. One example of this will be to provide the student with a quota of finished tasks versus total tasks, as well as a graph indicating their progression towards the final goal accompanied by a prognosis. The prognosis indicates whether the student is expected to finish every task in time based on their current studying speed. Showing these statistics will contribute to an understanding of the student about its position and will possibly increase its motivation.

The characteristics of *cooperative* and *results-oriented*, mentioned by Prensky (2003) to have a positive aspect towards motivation, could be seen in this part of the prototype. The cooperation is represented by the *Helpful*-function (see figure 9) that encourages students to collaborate and to help each other with school tasks. Having the *Prognosis*-function and the illustrating graph (see figure 9) involves the result orientation-aspect to the prototype.

To prevent students from missing deadlines and to bring a sense of control, upcoming and completed tasks will be shown. This simple function was named "***Upcoming tasks***" as shown in figure 7. This function will be a part of the system in order to increase efficiency and to provide the student with a "*quality of life*"-feature having all information in one place. This specific part is not considered to enhance learning but is seen as valuable to include in the prototype.

The presentation of accomplishments and statistics could backfire in some cases. Students could experience a feeling of relaxation due to them being so far ahead according to the statistics. This can result in their study time dropping and in worst cases not finishing in time. Another plausible scenario is when the statistics indicate that the student is too far behind, which may result in the student feeling that the goal is impossible to reach and because of that not willing to try reaching it. Some information that is shown might be a stressful indicator for some and could therefore reduce their willingness to study or use the functions. A possible counter for this could be to enable the student to deactivate certain features and statistics, to use the values they deem are noteworthy or encouraging.



Course	Total amount of tasks	Finished tasks	Quote of finished tasks vs total	Average grade
Biology 1b	12	3	25%	C
English 2b	6	2	33%	B
Mathematics 3c	12	6	50%	A
Swedish 1a	10	4	40%	C

Figure 9. Mockup for the subpage of the statistics-function.

When it comes to the relation between these functions (progress and statistics) and IoT the ability to collect different types data and by combining the data makes it is possible for the system to find different patterns to provide the student with relevant information. The process of collecting data about a student's results, combining that data with other results or achievements and extracting relevant information for the student to take part in, distinguishes the IoT.

Interaction

The usage of social media was mentioned by the teachers in the first focus group to be one of the reasons behind the difficulty in keeping focus. The fear of missing out and overall notifications disturb the students, as scrolling the feed has become something done by routine. Implementing a similar function in the form of an "***Activity feed***" with school-related happenings meets the reality and uses the power of interaction to increase motivation. This activity feed will bring competitiveness and a new way to cooperate, which is in accordance with Prensky's (2003) statings about what is important for the motivational aspect. The activity feed needs to be voluntary in the way that the student chooses what kind of post that is to be shared and the default setting of the feed-function will be to not post anything. Posts can be created manually by the student or generated by events. These events could be when a student finishes a task or when they require help with a problem. To avoid a "popularity contest" no like-button will be available, but comments for discussion purposes will be enabled. There will be no anonymity setting for this function in order to reduce the risk for cyber-bullying. The teacher will be able to see the posts and comments and thus create a supervised environment in which bullying will occur to a lesser extent. Visualization on how the interaction-function could be presented in the opening page is shown in figure 7.

It may not be possible to eliminate the risk for cyber-bullying entirely but it is of dire concern to try reducing it as much as possible. This function opens up another channel for that to happen which occurs whenever a new line for communication is introduced. Another problematic aspect of this function lies in two extreme situations. If the activity feed creates an environment where no postings are done at all, students may hesitate to post with the fear of standing out. In the other end, the activity feed could create an environment where postings are done in a large frequency and where students feel a necessity and forcing to be involved in that same posting-rate.

This interaction-function as a part of the whole system is dependent on the other functions. The IoT in this function hence indirectly exists through the interconnection with the rest of the system and its functions.

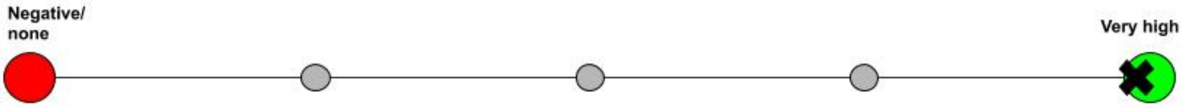
3.3.2 Micro-phase 8: Evaluation

Even if the prototype is developed from grounded ideas from active teachers, proper analysis and evaluation of it are considered to be required in order to validate its potential. This evaluation was done by conducting a semi-structured interview with a person possessing expert knowledge in the area of Swedish upper secondary school. The interviewee is the chief of staff in the educational department for upper secondary schools in the county of Stockholm and has a different insight to the area than the teachers that previously participated. By presenting the developed prototype in an explanatory manner to this second party, a valuable and more unbiased evaluation of the prototype and its potential was collected.

The interview was constructed in a semi-structured manner. It was initiated by a short explanation of IoT and this research study, followed by a more extensive description of the prototype and its functions. Figures 7 and 9 were used in combination with explanations and examples to provide the interviewee with an in-depth understanding of the prototype. The interviewee showed an overall positive attitude toward the prototype and the concept of implementing an IoT-based system to enhance learning. It was stated by the interviewee that the subject of digitalization is a key factor when discussing how school should evolve and that a majority of school management meetings are about IT-related matters.

The interview was centered around three different questions where the answers were given both in scale-form and with a complementing reflection. The first question seeks for the opinion about the focus aspect of the prototype, while the second question does the same but for the motivational aspect. These two questions have been responded in both an explanatory and a five-scale matter, where the scale goes from *Negative/none* to *Very high*. The third question is formulated to capture an opinion about how realistic the prototype is, foremost in the near future. The questions and the essence of the answers are presented below.

To what extent do you think the focus aspects of this prototype could be used to enhance learning (Negative/none to Very high)? Why/why not?

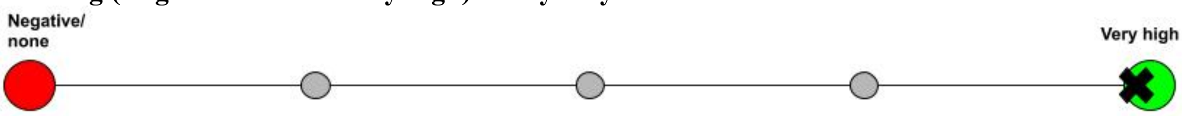


The interviewee confirmed that notifications are a problem due to their distractive nature and responded positively to the idea of using their functionality to “distract” the student back into studying. The interviewee mentioned that: *“Psychological triggers could work as a way of deceiving the brain in a positive way”* (Interviewee, personal communication, May 7, 2019).

The way of using data to learn about individual behavior and using that to assist the student was definitely considered to be effective and in that turn to enhance learning. The interviewee stated that: *“The individualization of notifications and alternatives is well suited with the idea of that every student has their own way of learning, which I agree they do have.”* (Interviewee, personal communication, May 7, 2019).

The risk to instead disrupt the student was brought up but quickly dismissed since the notifications could just be ignored.

To what extent do you think the motivation aspects of this prototype could be used to enhance learning (Negative/none to Very high)? Why/why not?



The interviewee could see an impact on student motivation based on the functions of the prototype and thus also have a positive impact on learning. Several reasonings from the interviewee was of value and are listed below as direct citations (Interviewee, personal communication, May 7, 2019):

> *“The function of visualizing progression in form of accomplishments and task management could definitely provide the student with a valuable insight of its position within each course, and encourage the student and increase its motivation.”*
>
> *“This idea about the prognosis will be of great value, I’m sure. This one I really like. I could provide powerful warnings when the student is falling behind, which can help with motivation before it is too late.”*

"Self-reflection is something that I actually have thought about, especially when it comes to students that may have a harder time in school. So showing statistics that are of importance and relevance for the student surely could help the student to for instance improve its studying technique."

"What I like about this interaction-function is that it is close to reality and recognition is something that I think is important for students motivation."

Ethical issues were raised due to the vast collection of data. However, the interviewee saw no problem with this in practical senses if the student (or parent) had the opportunity to turn it off and only use it when and if they want to. Competitiveness was another concept that the interviewee mentioned could be of issue. Elite schools could use such a system to create a contest, which would not be of the best interest for student's general health and attitude towards school.

Is it a reasonable assumption that this kind of prototype could be implemented today? Why/Why not?

The interviewee was very positive about implementing this sort of solution in near time and stated that:

"The power of using data to assist the student and increase its motivation is something that is very interesting and likely to be seen in many schools soon. The education departments in Sweden are frequently working with these kinds of questions and the subject is discussed very often." (Interviewee, personal communication, May 7, 2019).

The interviewee was certain that these kinds of solutions and interventions are going to be seen in a large extent within the near future and proclaimed the notion that schools must adapt to fit into a digital society.

3.3.3 Micro-phase 9: Analysis

The developed prototype resulted in a relatively low-fidelity presentation of it in the form of static figures. Focus was laid on the core functionality of the prototype and not as much on how the functions were presented visually. It was important to keep the opinions and reflections collected from the teachers as a foundation through the entire development, in order to develop functions with a concrete relevance.

The evaluation of the prototype had great importance for assessing its potential of succeeding in school settings and more specifically if it would enhance learning. By allowing the interviewee to both answer concretely with the scale and speak freely, a general understanding of the prototype's impact was collected. The responses showing maximal turnout to the positive side on the scale and a positive attitude in the reasonings indicates that the prototype has great promise in today's school. The system based concept provides the prototype with extra value than if each function would stand on its own.

The functions with motivational-aspects (upcoming tasks, accomplishments, activity feed and statistics) would feel this effect even more due to their heavy reliance on each other. In general, more functions and data collected in a system enables the system to combine this data in several ways, which can lead to valid results of great variety. If the system in this prototype would add further data collection streams, it would provide with the power of extracting deeper statistics or finding better alternatives to suggest for the focus keeping.

Using a sensor such as a webcam to gather data would provide new possibilities such as assessing whether the student is looking on the screen, or if the student is writing in a book. Some webcams might even be advanced enough for eye tracking and thus enables for a more intricate system of analysis to take place. However, the functions used in this prototype are deemed sufficient in order to help the student in motivational and focus related matters, which in turn enhances learning.

The overall outcome from meso-phase 3 was a prototype with IoT-functions developed from opinions collected from teachers, and also an evaluation of that prototype from an expert in the school area.

4 Discussion

The research question for this study is formulated as: *"Based on challenges that have emerged in school from the digitalization, how can IoT be used to enhance learning?"*. In order to answer the research question in a proper way, both the necessity to investigate what challenges have emerged from digitalization and how a possible IoT-intervention could be designed was needed.

4.1 Findings-discussion

The findings in this study showed that digitalization has changed the school environment and affected challenges as *focus-loss*, *technology dependency* and *tendency to take shortcuts*. The course of direction, to proceed with the challenge of *focus-loss* occurred mostly due to the high frequency shown by the content analysis of the material from the first focus group.

Identified challenges

The challenge to keep students focused during longer periods came from the participants in the first focus group. Even if the focus-loss is not a new challenge due to digitalization, the causes of it have changed. The teacher-statements told that smart-phones, notifications and social media were possible causes of focus-loss today. The study by Jacobsen & Forste (2011) showed that 62% of that study's participating students used some sort of electronic media while they actually were supposed to study. This shows that a majority of students, as early as 2011, were distracted by preferring activities on electronic media instead of school-related activities. The further mentioned upward digital trend by Jacobsen & Forste (2011) and the statements from the participating teachers in the first focus group confirms that digitalization has affected the causes of focus-loss. With the participating teachers' belief that focus-loss affects learning and the results from the study by Egong (2014) showing that academic performance increases with a good ability to stay focused, focus-loss could likely affect learning. This mix of theoretical and empirical ground strengthened the relevance of the *focus-loss* challenge for this study to proceed with and explore how IoT could be used to manage this challenge.

Involving the *motivational* aspect in a later stage than the *focus* aspect did not affect the outcome of the study. Similarly, to the *focus* aspect, motivation is not a challenge of new occurrence but the causes have shifted with the digitalization as a probable cause. *Motivation* and *focus* could be considered as being related to each other since, in a way, the ability to maintain *focus* could improve from a high *motivation*. This assumed relation contributed to involving *motivation* as well in the IoT-solution. The collected opinion from the teachers in the second focus group, with support from the study by Arens et al. (2015), made it possible to consider that motivation through self-perception could enhance learning. With a diverse *motivation-term* with several different characteristics to it (Tuan et al, 2005), the authors of this study set a stipulative definition to *motivation*, something that could have led to slight bias on the findings. If the stipulative definition would have been set in a more abstract matter, or if a definition from another study would have been used, the motivational aspect may have had a different role in the result. To motivate the students to exercise or to eat regularly might also have enhanced learning in some way, but with a motivation-definition with a directive to initiate school tasks, the resulting role of motivation was rather narrow.

All the identified challenges from the first focus group could be of importance when wanting to evolve schools to properly fit into a digitalized society. When the choice of direction was made to tackle the loss of focus challenge, it did not indicate that the remaining challenges were less important or non-existing. The contribution of identifying these challenges has an important part in the study.

The choice of direction with the focus challenge showed later to involve the motivational challenge as well. Even if the motivational challenge had a low frequency in the first focus group, involving it was encouraged due to the confirmation of its existence in the first focus group and the persuasion from the teachers in the second focus group.

Developed IoT-functions

The proceedings in this study with *focus* and *motivation* as withheld challenges led to finding out how IoT could be used in order to manage these challenges and enhance learning.

The "*Study mode*"-function that provided assistance to students to keep *focus*, was originated from teachers ideas, developed by the authors and supported by theory. By keeping focus during longer periods of time, longer learning periods will take place and in turn, that probably will enhance learning. The statement from the teachers in the second focus group that all students have individual needs inspired to include the possibility for the system to learn about students behavior and adjust accordingly. If this learning ability of the system had been excluded, the effect could have been the opposite from the wanted. The identification of focus loss would only have been based on predetermined parameters, which could lead to incorrect identification of focus-loss and inappropriate suggested actions. This could result in the unwanted situation of the system being a disturbance instead of assistance. The system's learning ability was made possible with the power and potential of IoT.

The "*Statistics"* and *"Achievements"*-functions were developed to help the student in motivational matters by increasing the student's self-perception of competence in different areas. Making the student aware of its competencies in each course could lead to a higher frequency of study sessions, which in turn could enhance learning. Another function implemented in the system with the purpose to increase student motivation was the "*Interaction*"-function. The interaction between students through the system could trigger the student to initiate a study session due to the different posts by other students, which in its turn could enhance learning. A possible negative effect of this function could be developed if the interaction creates a competitive environment. The stress levels of the student could increase and the learning ability then decrease. The combination of data from the interaction between the functions and the student was made possible with the power and potential of IoT.

By managing the challenges of *focus-keeping* and *motivational gain* with the presented IoT-functions interconnected as a system, the possibility to enhance learning in today's school-environment is considered to be plausible.

When looking at the possibilities, there are other IoT-based data collection sources from which interesting functions could be developed. A webcam could gather data about the student movement, eye tracking and if they even are present by the computer or not. This would not only open up for new functions to be incorporated into the system but it would also increase the accuracy of the functions already in place. However, it would also raise a new set of ethical issues, especially when minors would use the system. Another data collecting sensor could be a microphone for the collecting of sounds. This would enable the system to identify when a student is walking away or toward the computer as well as sighs, which could indicate different feelings. This would also increase the accuracy of the system but it would at the same time also raise ethical issues as with a webcam. A smart-watch or similarly would be a crucial data collection source for physical education. It would enable for a gathering of student's movement and its heart rate, which could be used to assess the student's activity in those classes as well as the overall health of the student. This would not affect the performance of the prototype in this study, however, it would build on it and enable for new functions to be used to help the student gain insight in their overall health, which is a factor in learning.

A vast amount of data being collected by the suggested prototype opens up for different ways of using that data. Being able to generalize the data could make it possible to find problem areas for specific schools and also for the entire school system, and use that to identify potential improvements. The possession of such data could also be used for other purposes, which will have their own societal implication. For instance, it might be possible to gain insight about student's well-being and overall health as well as their preferences in school, which could enable to create "profiles" of them. This kind of data usage has different ethical issues and can affect society in different ways.

This study used a rather broad definition of IoT by not limiting it to interconnection between physical objects but also the virtual interconnection as well as the interaction with humans. This definition which was inspired by the study performed by Hernwall and Ramberg (2019) is reflected upon the entire design process and the result. With a narrower definition of IoT to only include the interconnection of physical objects, the input from the teachers as well as the design process and result would differ from what it became in this study.

Prototype evaluation

The final evaluation of the prototype did support the claim made by the teachers, that motivation and focus keeping can be affected by these functions and as thus be used to enhance learning. The ability to realize an implementation of the prototype also got discussed where it was stated that there would be an increasing amount of interventions like the one in this study in future schools. This leaves the question of why IoT-interventions are not implemented to a wider spread already and what will be the starting point for that to start happening in school. The importance of a digitalized school was stressed as many of the management meetings involve digitalization as the main topic. This indicates that studies like this are of relevance today and that there will be a change in schools in the near future, but again it is interesting to discuss what will break the ongoing discussions into becoming actual implementations. The great potential of IoT is shown, the challenges are there and the participants in this study shows great encouragement in using IoT to enhance learning.

4.2 Methodology-discussion

The progress of the study experienced some obstacles that resulted in some changes in direction. These obstacles where although not critical to the extent of hindering the study from producing a valid result. However, the obstacles did have an impact on the research structure.

Research structure – Was this really a DBR?

This study was initiated with the ambition to follow the guidelines of DBR. However, as the study progressed, it was noted that several elements could be more in line with action research. Due to various constraints such as time and resources, the number of iterations was less than what is recommended for a DBR study in the literature. The general notion that DBR is better suited for larger studies was felt during this study. Being encouraged by the article written by Pool & Laubscher (2016), saying that DBR is suitable for short-term projects, the suggested research structure proved to not be optimal for this particular study.

The limitation of not being able to schedule longer focus group-sessions than 1 hour slowed down the progress of achieving a result. If it would have been possible to arrange maybe 3-hour sessions or even full day-sessions, this study could have gathered the data about challenges and possible solutions sooner and more time would have been available to iterate the prototype development. Having several iterations for prototype development is of importance in DBR, which was not the case in this study. Even if the number of iterations was not sufficient in this study, other features and requirements for DBR were met. This study is considered to have generated a relevant intervention to complex educational problems with scientific insights, in accordance to Bakker & van Erde (2015) and also to have clarified problems of teachers and learners, in accordance to Pool & Laubscher (2016).

Data collection and analysis

When conducting the focus groups, it was of great importance to the study that all the main ideas and opinions came directly from the participating teachers in order to increase the validity of the study. If the authors would have interfered and suggested different challenges or solutions and IoT-functions, the results would have caught a bias from the authors. Since none of the authors are educated teachers, that kind of bias would have been deceptive to how the reality actually is. The authors put their subjective minds when developing the functions, but the important part is that the main ideas came directly from unbiased teachers and also that the evaluation came from a person with great knowledge in the area.

A similarly conducted focus group with another group of teachers may not have yielded the same challenges as the ones in this study. A different result from the focus group would have shifted the direction of this study and changed the outcome. Different backgrounds, experiences and even mood on the current day could affect the responses from a participating group of teachers.

Working in a school with a technological and innovative nature, as the participating teachers did, was considered to contribute with valuable inputs to this study. A tendency to be involved in similar projects that are technological and innovative has probably created an experience in the subject. Schools without the same technological and innovative nature could have different experiences and suggestions than the ones identified in this study. By only including one school, with its particular orientation, the participants may not be representative of the entire population of Swedish upper secondary schools.

A lack of experience from the authors of collecting data through focus groups may have affected the quality of the findings. The focus groups were planned in advance with the main question to answer, but the importance to sense the situations during discussions and decide when to interrupt, ask questions or lead the participants in certain directions was difficult and may have affected the collected data. Even if this was not a big issue and the focus groups were considered as successful overall, the authors lack experience should be noted.

The content analysis of the material from the first focus group set the course for the study to tackle the challenge "loss of focus". As mentioned previously, the high frequency of this challenge does not indicate that the rest of the challenges are less important or less relevant. A reason for the high frequency, other than the fact that focus loss is indeed a big challenge, could be explained with focus-loss being a rather obvious and easily noticed challenge by the teachers. The interplay of having the motivation to initiate a study session and the ability for the student to keep focus during that time was determined to have a strong impact on the student's capacity for learning. The teachers in both workshops laid the foundation for which the prototype was developed, while the evaluation of it was from a management perspective.

Evaluating the prototype to find out its potential could have carried more weight if it had been conducted with more experts involved. A focus group with several experts from various backgrounds as participants could better the evaluation by providing a more holistic view. Due to the difficulty in finding already busy persons wanting to participate in this study, involving more persons in the prototype evaluation was not possible. A shortage of time and no possibility to offer compensation for their time contributed to not having more persons involved. However, the collection of opinion from one expert is considered to have given enough for the scale of this study.

5 Conclusion

The research question of this study is considered to have been answered in a proper way, which implies that this study was successful. The presented IoT-based system was developed to help the student in motivational and focus-related aspects. These aspects proved to have a direct impact on learning, which in turn led to an IoT-based prototype showing how IoT can be used as part of a system to enhance learning.

RQ: Based on challenges that have emerged in school from the digitalization, how could IoT be used as part of a system to enhance learning according to upper secondary school teachers?

Answer: To manage the identified challenges of *focus-keeping* and *motivational gain*, IoT can be used in the form of making it possible for a system to learn about *student behavior* and *student performances* by collecting relevant data. By combining and analyzing this data, the IoT-system could help students by providing different *suggestions to keep focused*, *show accomplishments*, *show an activity feed* and by *showing encouraging statistics*. Providing students with this is considered to contribute with better circumstances to keep focus and to raise motivation, and by that; enhance learning.

Several challenges in school were identified, where focus and motivation were the challenges that were proceeded with. The participating teachers provided these challenges with the meaning that both have an impact on learning and that digitalization has affected them or their causes. It was important for this study that the ideas simply came from the participating teachers, without any bias from the authors.

Jacobsen & Forste (2011), Egong (2014) and Uzelac et al. (2015) where studies mentioned in the theoretical background that agreed about focus having an impact on learning. Malmberg & Helmersson Olsson (2016) and Jacobsen & Forste (2011) implied that digitalization had modified the causes of focus loss.

Rahardjanto et al. (2019), Alhadi & Saputra (2017) and Dislen et al. (2013) were studies that agreed about motivation having an impact on learning. Prensky (2003) implied that digital media has affected the attitude towards school in a negative way.

This alignment between empiricism and theory supports the claim that the challenges of *focus* and *motivation* are affected by digitalization and has a direct impact on learning.

The participating teachers suggested different possible IoT-functions that could manage the challenges of focus and motivation. The functions that were included in the prototype were Study mode, Achievements, Statistics, Activity feed and Upcoming tasks. All of these functions had origin from the participating teachers, which again was of large importance for the relevance of this study.

Kallookaran & Robra-Rizzants (2017) used notifications to assist students, which is in accordance with the characteristics of the *Study mode*-function.

The *Statistics*-function and the *Achievements*-function are in accordance with Arens et al. (2015) who stated that self-perception of competence was important for motivation.

Again, with the alignment between empiricism and theory, the developed functions imply on how IoT could be used as a system in school matters to enhance learning, which is a part of showing the stated large potential possessed by IoT (Saritas, 2015; Moreira et al, 2017).

The findings of this study and the conclusion of it could be used as an indication for upcoming implementations of IoT in school. The identified challenges and suggested IoT-based intervention could function as guidelines for where to begin. The presented results are considered to be of relevance and value, even if the quality of this study was rather limited.

Research quality

The credibility of this study may have been affected due to the inexperience of the authors to moderate focus groups. Without any previous experience, the ongoing discussions could have diverted from the topic and discussions could have been interrupted in wrong occasions, leading to a slight loss of credibility on the collected data. Another aspect that could have decreased the credibility is the possibility that the participants did not entirely understand what was expected from them. Even if the opportunity to ask questions and to request deeper explanations existed, it is possible that the credibility decreased due to a possible misinterpretation from the participants.

Another aspect that might hurt the credibility of the study is the relatively small sample size in the focus groups. The small sample size in addition to the participants being active in the same school may not be representative of the entire population of active teachers.

The confirmability could have been affected due to the conduction of content analysis. The procedure of content analysis provides the frequency of certain responses from the participants. The responses were analyzed and categories were counted when mentioned in a certain context, which might indicate a slight bias from the authors and thus reduce the confirmability of the study. Another aspect that influences the confirmability of the study was the evaluation interview with the expert. The quotes were chosen in a selective manner by the authors, which might not represent the responses from the interviewee to a full extent. However, this potential bias was countered by using a scale from which the interviewee could respond in a concrete way. The way of gathering responses in an explicit manner reduced bias from the authors and thus increased the confirmability.

Future studies

A recommendation for future studies of this scale is to either include more iterations or incorporate a different methodology such as action research in order to produce a result more efficiently. Furthermore, it would be of interest to determine the cause of the delay of IoT-based solutions in schools. The prototype in this study was evaluated to be not only plausible to implement today but also sought after. The possibility to include even more IoT-functions and hence more data gathering and data combination is also something that would be interesting to investigate. With this comes ethical aspects as it often does when collecting data and also when investigating the matter in the pre-university education is where minors are included. Thorough research about what IoT-interventions would be possible to implement from an ethical point would therefore also be of interest. To gain higher credibility than the one possessed in this study, it would be of import to have a larger sample size and to include participants from different schools. It would also be of great value to include students in the data collection as they may provide a different view to the intention of learning enhancement. Finally, continuing this study by starting off where it ended could lead to the completion of a thoroughly developed prototype and is welcomed by the authors of this study.

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Appendix A – Informed consent form (Swedish)

Samtyckesformulär – Examensarbete 2019

Denna studie avser hur användning av IoT kan främja lärande i svensk gymnasieskola. Studien ingår i det examensarbete som utförs av Jonathan Bertilsson och Kristoffer Bodin för data- och systemvetenskapsavdelningen (DSV) på Stockholms Universitet. Examensarbetet tar slut i början av juni och resultatet kommer i första hand att delas med lärare och intressenter inom DSV. Resultatet kan även komma att användas i ett större projekt om IoT i skolan (iothub.se). Deltagarna i denna studie erbjuds ingen ekonomisk ersättning, endast tacksamhet från Jonathan och Kristoffer. Resultatet av studien kan delas till deltagarna i slutet av arbetet, om så skulle önskas. I insamlingen av data i form av workshops kommer det att förekomma ljudinspelningar samt fotografier (ej på personer). Ljudinspelningarna kommer att transkriberas till den mån innehållet är av intresse och därefter kommer ljudfilerna att raderas.

Inga personliga uppgifter av deltagarna kommer att inkluderas i studien, vilket innebär en anonymitet för de som deltar.

Deltagarna föredras att inneha titeln lärare för att fånga studiens syfte.

Deltagaren i studien kan när som helst avbryta sin medverkan i studien och få samlad data raderad.

Som deltagare samtycker jag härmed om ovanstående och godkänner medverkan i denna studie, inklusive användandet av ljudinspelningar och fotografier.

Datum och deltagarsignatur:

____

Datum och moderatorsignatur 1:

____

Datum och moderatorsignatur 2:

____

Om deltagaren önskar ta kontakt med någon av moderatorerna skickas en e-post till bertilssonjonathan@---.com, där Jonathan Bertilsson ansvarar för ärendet ifråga.