How can Internet of Things (IoT) change learning?

Teachers' perspective

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Abstract

Nowadays, technology is advancing and society must adapt to these changes and education is a field that will follow this progress. Internet of things (IoT) is a new technological concept based on sensors that according to literature can show signs of pedagogical potential if integrated in schools. This thesis studied a group of Swedish teachers' perspective on what pedagogical potential they find in IoT integration and how they think IoT can change learning conditions. For this purpose, a workshop with 5 participants was held, an online questionnaire was handed out and answered by 28 people and interviews were performed with 4 respondents. Thematic analysis was performed on all data collected and new concepts were produced based on grounded theory research strategy. The main findings are that, according to the respondents, IoT can create personalized, adapted to individual, learning and that school of the future might be reformed if IoT is integrated. Personalized learning means personalized feedback, students' monitoring, personalized educational material. These new features might lead to school reform in the sense that teaching will take place distantly, teachers' role might change and school system might be "trained" to perform better through the analysis of the data gathered by sensors. However, there were those who thought that IoT integration can create ethical issues, because of data privacy related concerns.

Keywords: *IoT, education, teachers, technology-enhanced learning*

Synopsis

Background	This thesis belongs to the area of technology enhanced learning. Education needs to be developed as pupils' demands keep increasing. Technology can help towards this direction and IoT is a technological concept that might show good potential. Since teachers are a basic component in the teaching-learning procedure, their perspective on how a new digital tool can be introduced in the classroom is of great value.
Problem	IoT tools have already been introduced in education in both administrative and pedagogical concepts. Even though Sweden is one of the most technologically developed countries in Europe, little research has been done in Sweden regarding IoT. Therefore, little is known about the pedagogical potential IoT can show, especially regarding Swedish teachers' perspective.
Research Question	The research question this thesis answers is the following: From a teacher perspective, how can IoT change the conditions for learning in formal education?
Method	The research strategy followed is grounded theory. The empirical data for this study was gathered through observation, a questionnaire and interviews. Some interviews were also performed after the data gathering, and the data proceeded was used as a validation method. All data was analyzed with thematic analysis and concepts based on grounded theory were produced.
Result	According to the teachers, IoT can offer personalized learning to students according to their needs and preferences. The teachers' role, the students' position and the school system might possibly change if IoT is to be integrated. Education might take place distantly and schools might have the possibility to be "trained" in order to perform more efficiently. Personalized learning as described in this thesis can be interpreted as a transformation in practices followed by teachers that might lead to alternations in already existing learning theories and transformation of future school. However, there are concerns that IoT can create ethical questions related to data privacy.
Discussion	Limitations: The author's inexperience in research might have hurt this thesis' reliability. A validation technique was used to increase the validity of the findings. This study cannot be

	considered transferable due to the relatively small sample of participants. Social implication: these changes in education can bring society transformation since these two fields are interrelated. Ethical question: data privacy and whether education can be trusted in such a questionable technology. This thesis is valuable for future IoT integration and its contribution to higher quality learning. The Swedish teachers' perspective regarding the pedagogical potential had not been studied before in the same way.

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List of Abbreviations

ICT: Information and Communication Tool

IoT: Internet of Things

IRS: Integrated Reception System

LA: Learning Analytics

MIT: Massachusetts Institute of Technology

NFC: Near Field Communication

RFID: Radio Frequency Identification

SDT: Self-Determination Theory

SSIS: Stockholm Science & Innovation School

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1. Introduction

On its report, the Swedish Parliament points out the importance of research on availability and use of digital tools at schools, as, in that way, it is reported how digitalization in schools can contribute to an overall development on the society (Riksdagen, 2016). SkolDigiPlan is an initiative that describes the work done on digitalization in the school system and how the school headmasters can work in order to achieve the goals of the national strategy created by the Swedish government, by 2022. These goals are mainly related to the three following directions: digital competence for everybody in the school system, equal access and possibility to use for everyone, research and follow-up about digitalization potential (Utbildningsdepartementet, 2017). The significance of this thesis is greatly supported by the aforementioned suggestions made by the Swedish government.

As the number of students per classroom keeps increasing, educators' concern on how they can comprehend students' learning requirements gets more serious. It is the educators' main role to identify the right technology and integrate it in a way that learning will be enriched and enhanced (Aldowah, Rehman, Ghazal, Umar, 2017). Cloud computing, ubiquitous computing, artificial intelligence (AI) and data mining are fields which have contributed to the new era of the e-learning since any information can get available *"anywhere*, *anytime"* (Hussain, 2012). Starting from e-learning (electronic), learning then proceeded to m-learning (mobile) and u-learning (ubiquitous)[1] and now it's time for the IoT-supported learning (Casey, 2005).

Some functions, concepts, theories and relations that frame IoT as stated by Hernwall & Ramberg (2019) are illustrated on the picture below (see fig. 1).

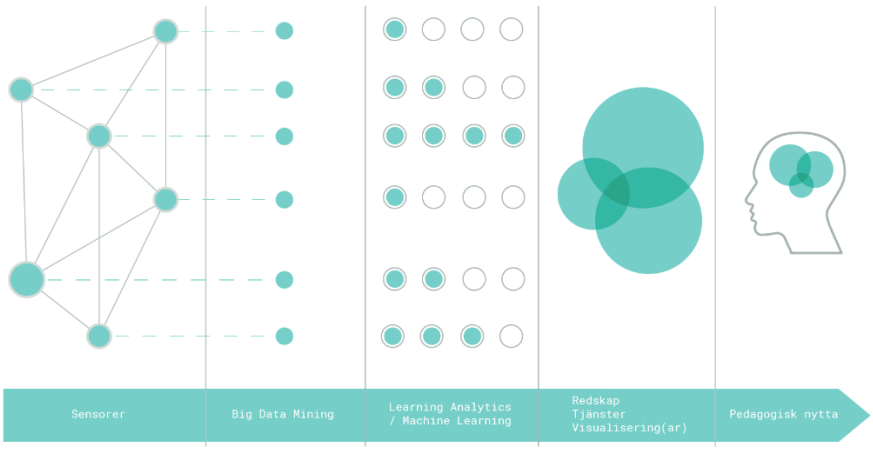

Figure 1 Functions, concepts and theories that frame IoT (Hernwall & Ramberg, 2019)

[1] *"Ubiquitous computing (or "ubicomp") is a concept in software engineering and computer science where computing is made to appear anytime and everywhere." ("Ubiquitous computing," n.d.)*

With Big Data Mining, data can be collected through sensors that exist in IoT tools. This data can be analyzed within Learning Analytics and can show pedagogical results. These results might show potential interventions in the learning/teaching procedure (Hernwall & Ramberg, 2019).

IoT tools can contribute to a general revision of the educational system and the main aim of integration of IoT in education is a change in both learning and teaching by creating new, innovative methods for learning (Gonzalez, Organero & Kloos, 2008; Gómez, Huete, Hoyos, Perez, Grigori, 2013). Meacham, Stefanidis, Gritt & Phalp (2018) discuss how personalized education, according to students' needs and with feedback on teaching, can help teachers improve their work as well as improve learning outcome according to what their implemented prototype results showed. Other researchers have designed IoT tools in order to test students' performances and learning output (Domingo & Forner, 2011; Getso & Bakon, 2017; Gonzalez et al., 2008; Gómez et al., 2013; Suduc, Bîzoi & Gorghiu, 2018;). Gómez et al. (2013) talked about IoT enhanced teaching methods that can improve students' performance, and Mechlova and Malcik (2012) believed that learning needs and theories must be reconsidered taking into consideration technological changes. However, some ethical issues can exist concerning personal data, their integrity and privacy as one can never know how data that is collected via an IoT tool can be used (Hylén, 2019).

In 1999, Kevin Ashton was the first to introduce the term of Internet of Terms in order to define a system that is connected to the internet via sensors ("Internet of Things", n.d.). All big industries invest funds on new technologies and the paradigm of Internet of things will affect all users', both private and business, everyday life. E-health, e-learning, assisted living, automation, logistics and transportation are only few fields where it will be applied in (Atzori, Iera & Morabito, 2010). As Hernwall and Ramberg (2019) suggested, IoT and sensors have already been applied in smart home or other technological applications. However, since educational changes and technological ones are decided by completely different stakeholders, they concluded that education and technology are two fields growing and developing in parallel and no dialogue between them takes place. Therefore, educational goals concerning technological changes might not be prioritized (Hernwall & Ramberg, 2019).

Internet of Things (IoT) is a technology defined as "*an emerging networked infrastructure penetrated by embedded smart devices, called things, which have identities, sensing-actuating and computing capabilities, are connected via the Internet, can communicate with each other and with humans and can provide semantics of some useful services*" (Štuikys & Burbaite, 2018, p.327). In the concept of IoT, "things" interact and interrelate with their close objects in order to share information. Such objects are sensors, mobile phones and tags (Atzori, Iera & Morabito, 2010; Giusto et al, 2010).

Due to broadband internet's widespread coverage, nanotechnology included in devices and the growth of IPv6 protocol, devices can now be more easily interconnected (Gómez et al., 2013). According to statistics, the number of interconnected things is greater than the world population the last 11 years and this number is expected to reach 50 billion by 2020 (Jain, 2018).

1.1 Research problem

Sweden is characterized as one of the countries in Europe with the most technologically developed education system. Along with Denmark and Norway, in Sweden, the ratio of computers per student connected to Internet is one of the highest in Europe. That goes along with the fact that Sweden has one of the highest bandwidth in Europe and is developed when it comes to virtual learning (European Commission, 2013). However, teachers in Sweden have been reluctant when it comes to ICT, something that was stated both by Erixon (2010) on his research and in the European Commission's report on ICT use in education (European Commission, 2013).

The research problem the current thesis addresses is that even though IoT holds promises about a more student-oriented learning, still little is known about what potential teachers see in IoT integration. This is important in the overall strive to develop the quality of the Swedish school. There has been research about ICT integration in school, but there is a lack of knowledge about what teachers in Sweden think of IoT.

1.2 Aim and objectives

This study's aim is to explore a group of Swedish teachers' perspective on IoT in learning. The current research's objectives are to identify how those teachers believe IoT integration can change conditions of learning. Results might be useful for future adoption of IoT tools in Swedish (not only) schools.

1.3 Research Question

RQ: From a teacher perspective, how can IoT change the conditions for learning in formal education?

1.4 Limitations of the study

The current research was conducted in cooperation with teachers throughout Sweden and researchers that are part of the *IoT hubb skola* project. This study focuses exclusively on the teachers' perspective. Other related and future studies could include students' or headmaster perspective. Also, this thesis studies potential IoT integration in formal education only, not in informal or semi-formal.

1.5 Thesis structure

The thesis will have the following structure:

- In chapter 2 the reader will find a literature review of the subject as well as a description of relevant research.
- In chapter 3 methodology is stated. Research methods and strategies for data collection and analysis used will be mentioned and it will be argued how and why they were chosen. Also, some ethical aspects regarding the data collection and strategies will be stated.
- In chapter 4, findings proceeded by the data collection will be developed and discussed according to existing literature.
- In chapter 5, the study's findings will be deeper considered and further evaluated.
- In chapter 6, research questions will be answered, research limitations will be described and future research will be suggested.

2. Extended background

In this chapter, a literature review related to the topic of this thesis and its implications will be presented. Pedagogical opportunities, suggested applications as well as implementations in Sweden and in the rest of the world will be presented, in order to frame the background for the current study.

2.1 IoT in education and its potential

In this sub-chapter, the potential of IoT in education will be examined as it was described in literature. Bottino (2003) suggested that teachers' cooperation, collection and documentation of good practice examples, curricular change, and life-long learning teachers as key indicators for schools' reform. Furthermore, she mentions the need for change in the educational strategies and the activities the students engage in. If these indicators can be validated with IoT, it means that IoT can contribute to school's reform.

On his dissertation, Kullberg (2011) tried to investigate whether teachers find teaching with ICT easier and if students could get a positive stimuli by this type of teaching. All teachers seemed to agree that ICT-enhanced teaching was more enjoyable and motivating both for educators and learners but also more time consuming. Wang (2010), suggested that English teaching could be enhanced through IoT, especially through visual sensors that would help students improve their accent. Sari, Ciptadi and Hardyanto (2017) wrote a report about the design of a smart campus in the UPY University (Universitas PGRI Yogyakarta) using IoT. The campus they described included three infrastructure parts: smart education, smart parking and smart room. According to them, smart education consists of e-learning, personalized learning and virtual classroom.

There will be a more analytical review of already proposed prototypes and systems and how they succeeded to create a new dimension on learning. More specifically, how technology-enhanced learning can create new learning theories perspectives, how IoT applications can be related to changed learning and teaching and how it can create other non-educational related opportunities and therefore reform school.

2.1.1 Personalized learning

More than 50 years ago, Cook and Ausubel (1968) claimed that the most crucial determinant for the teacher when it comes to learning, is to know what the person who learns knows already, so that he/she adapts his/her teaching accordingly. In their research, Meacham et al. (2018) mentioned the term *personalized education* and they discuss the integration of Internet of things in Higher Education. Personalization is an important feature that could be added to education since it can help the learners deepen their knowledge and cover their knowledge gaps. Promising applications that integrate IoT technology can be created and these applications can be used in class and track

personal behaviors and performances in order to create a more personalized material and feedback for the student.

Meacham et al. (2018) performed a case study at Bournemouth University (BU), in England where they designed a prototype that eventually helped teachers and students. It was a system that worked 24/7, it was available in lecture rooms and labs and, through a local network, it gathered and delivered data related to the users' behavior. It included an interface that would allow teachers to assess problems that would arise in class. The prototype was an IoT-based system that would gather data and was giving the teachers the chance to boost learning for students by giving them personalized feedback (Meacham et al., 2018). They concluded that IoT can create better methods for teaching and therefore a better future for the education, as it opens up for a more personalized learning to the students, according to their needs and weak points. A headband that could track brain activity and send the results to an application was proposed by Brown (2017). Teachers could then evaluate the monitored data and conclude to a curriculum based on what triggered students' positive reaction. (Brown, 2017).

Aldowah et al. (2017) suggested that teachers can use IoT to collect data on students' performance and involvement and create adapted teaching plans for future students. They concluded that gathering big amounts of data through IoT can influence students' and educators' response, behavior and accomplishments (Aldowah et al., 2017). According to others, students can become more independent and self-controlling by handling interconnected objects themselves, since they can be able to control their learning methods and experience and contribute to a more personalized education strategy. Their learning will then be aimed at their own needs and preferences, students can follow on their own pace and teaching will become more effective (Wang, 2010; Meacham et al.,2018; Gómez et al., 2013; Zhu et al., 2016).

Ashman, Brailsford, Cristea, Sheng, Stewart, Toms and Wade published a research in 2014 regarding personalized education and ethical and social implications for e-learning. They stated that since e-learning has come forward as a teaching method, learners have the possibility to individualize their learning and learning material can exist online and is not provided by a human, but rather from a computer (Ashman et al., 2014). According to Ashman et al. (2014), personalized learning can have good results on engagement, economy (fewer teachers, distant learning-possibility for more students) and learning outcomes. However, they also added the fact that social and ethical implications might come up. The concerns they mentioned were: personal data privacy, accuracy of inferencing, effect of personalization on individual capability and personalization on individual capability, personalization and the different forms of learning and assessment and the commodification of education. This comes to an agreement with what Hylén (2019) wrote on his report for IoT hub skola project concerning ethical and legal aspects of IoT integration in schools. The implications mentioned by Ashman et al. (2014) will be further discussed later in this text and in connection to the findings of this thesis.

2.1.2 IoT tools used in education

IoT tools have already been used in class or the school in a broader meaning. Some of them are applications for administrative purposes, some other concern tools that are used during the lecture by the teachers or students to enrich or support the educational procedure, and some others are applications used by the school as part of its premises (Bagheri et al., 2016; Meacham al., 2018; Charmonman et al., 2015; Mathews & Gondkar, 2017). Already applied IoT tools have already given good results and have shown interesting potential. More detailed, some suggestions are the following:

Gómez et al. (2013) from university of Gordoba, Colombia designed an implementation according to which students could use IoT in order to have a deeper comprehension about basic computer science concepts. This system integrated NFC technology and QR code scanners and the students could tag different parts of the computer in order to learn the basic parts of the computer but in a more innovative way. It was applied in two different groups and it was proven through the students' results that the experiment group's (IoT technology used) learning got actually deeper and their academic results were better than the control group's (traditional teaching).

Pireva, Siqeca, & Berisha (2013) proposed a wearable IoT tool that was based on RFID technology and students could scan it when they enter the classroom (Pireva, Siqeca & Berisha, 2013). Domingo and Forner (2011) designed a user-centered design that would expand learning environment virtually, by integrating IoT technology and concluded that they created a joyful way of learning for the students.

Tan, Wu, Li and Xu (2018) proposed a system for teaching management in a University in China that integrated QR code and RFID technologies. They applied those technologies in course videos, attendance monitoring, behavior recording and real-time interactive response. As a result of their suggested system, less distraction and higher attendance rates were observed. The system they suggested was a lower cost system in comparison to the IRS system. According to this system, the students could scan QR codes that correspond to exercises that are used as a helping material. They could get automated feedback and the teachers could have access to a real-time overall statistics that shows students' performance. That meant that the educator could evaluate directly the impact of his/her teaching and if there was observed low performance on a topic, he/she could decide to do changes in the teaching method or even the teaching material. Six teachers were asked to evaluate the system and all of them stated they believe this teaching can contribute to a higher quality level of teaching. They also claimed that students can get more interested in learning, teaching can be more efficient for teachers and the management of the teaching and education can be enhanced.

Farhan et al (2017) examined teaching performance and learning experience derived from the use of an e-learning prototype. They concluded that measuring students' visual attention can make them well-prepared and can create more independent learners. In addition, it can help students keep balance of their studies, it can improve feedback methods and teaching material can be used repeatedly. Meacham, et al. (2018) suggested that teaching and educational strategies can be

modified according to what the data gathered by an IoT tool shows and application of supported learning can lead to an improvement of teaching strategies. Getso and Bakon (2017) claimed that virtual reality technologies presence in education can promote different learning styles and make teaching and learning easier (Getso & Bakon, 2017). Sclater (2014) describes how data from information systems can contribute to Learner Analytics systems. However, this data cannot be evaluated in terms of quality and needs analysis (Gourlay & Oliver, 2013).

IoT tools can also enhance other student related concepts apart from learning. Bagheri & Movahed (2016) tested in-campus security in the Sookmyung Women's University (SWU) with the use of a tool that integrated NFC and RFID technologies. Measuring CO2 concentration and temperatures in classroom is an already existing technology. Wang (2014) suggested that IoT can be used in measuring the energy consumption in higher education institutions and she claimed that it could contribute to the development of a *green campus.* Consequently, not only can IoT help learning and change learning conditions, but it can also support other education-related applications.

It can be concluded that there are interesting results of IoT tools already tested in education. According to the literature presented, IoT application can provide alternative teaching methods and increase learning outcome, improved strategies through data gathering, easier, more efficient learning and of higher quality and administrative benefits.

2.1.3 Engagement and Motivation

Engagement is an important aspect and has been studied in relation to digital tools. When students were questioned, they stated that positive feedback that could make them happier could increase their engagement; students with long-term goals seemed to be more engaged and stress and control did not affect their degree of engagement (Bergdahl, Knutsson & Fors, 2018). Engagement seemed to differ throughout the different technologies use and during the day (Bergdahl, Fors, Hernwall, Knutsson, 2018). Students who had high level of tech skills showed higher engagement and according to Bergdahl, Nouri and Fors (2019), engagement in technology-enhanced learning is different than in the traditional classroom. When they studied Upper Secondary School students' engagement in connection to their performances, Bergdahl, Nouri, Fors and Knutsson (2019) concluded that high performers can be benefited by digital tools in class –they might use technology for learning purposes- and low performers engagement can be lowered even more since they might get distracted when they use digital tools. Nonetheless, the same thing that can be engaging for one group of students (high performers) might be disengaging for another (low performers) (Bergdahl, Nouri, Fors & Knutsson, 2019).

Reeve (2012) related engagement and motivation with learning using the SDT theory (Self-Determination Theory). SDT is a theory of motivation that describes motivation and the engagement proceeding from this motivation. According to SDT, students' inner motivation must be vitalized in order for them to get engaged. In order for the students to feel motivated, their needs should be heard during lectures. Reeve (2012) said that the way classroom functions can have a good or bad impact on student's

motivation and therefore engagement. Engagement is important because it enables learning, it can forecast students' good performances, it works independently to teachers' work quality and on its in-class form, it allows teachers to see the student's public engagement and therefore be more effective to their real-time feedback (Reeve, 2012).

According to the Self-Determination Theory (SDT), there exist five theories that have been developed in order to explain motivation. These are the following with a brief description each.

- **Basic needs theory:** psychological needs should be covered. Autonomy, competence and relatedness are the key characteristics
- **Organismic integration theory:** students preferably engage to interesting or enjoyable activities.
- **Goal contents theory:** this theory is about what the learner wants to learn through the learning process. It differs from the organismic integration theory in the sense that it focuses on status and good performances for example than on fun and mental pleasure.
- **Cognitive evaluation theory:** this theory is about the impact that a reward can have to students' motivation.
- **Causality orientations theory:** causality orientation theory is about different student personalities and orientations. It is about whether they choose to work autonomously or under educator's control.

Motivation and engagement are interrelated; motivation is more private and engagement more public, more observable. Therefore, motivated students become engaged students and that can show good results on students' learning. Engagement during a learning activity consists of four sub parts:

- **Behavioral Engagement**: Reeve suggests that one part is the behavioral engagement. It has to do with how attentive and concentrated students are when they are in class.
- **Emotional Engagement**: Emotional Engagement is about triggering of emotions in order to increase students' engagement and lack of emotions that can undermine it.
- **Cognitive Engagement:** Deep learning that doesn't stay on the surface is supported by this type of engagement.
- **Agentic Engagement:** In this type of engagement the learner is not a passive receiver and makes suggestions about the received knowledge.

If IoT can have the potential to change motivation, it can mean that it can modify engagement and learning. Later on this thesis, these suggestion made by Reeve (2012) will be compared to the findings of this thesis. If there are any relevant points, it means that there will be implications that IoT might be able to increase motivation and engagement for students and therefore improve learning.

2.1.4 IoT and learning theories

Mayer (2008) stated that psychology and education is a *"two-way street"* and that one challenges the other. Ever since the digital technologies have entered our lives, it has affected how people learn. According to literature, there has been implications on how IoT can enhance learning for students. Even though a concrete definition for learning is difficult to be formed, learning theories have been created and their aim is to describe the way humans learn (Alzaghoul, 2012).

Learning theories describe the variables that can affect learning according to their basic philosophy. This thesis will try to explore how teachers believe learning situation can change if IoT is widely applied to the learning process and if teaching can be modified. Mechlova and Malcik (2012) claimed that, since society is changing in the digital era, learning needs and theories that describe them should follow this change. According to Lowyck (2014), technological evolutions have affected the choices of learning theories and have changed the person in control from the teacher to the student. Mayer (2010) claimed that learning theories are increased along with an increase in technology-enhanced learning environments.

The four basic learning theories are often considered being behaviorism, cognitivist theory, constructivist theory and connectivism. There is a brief introduction about them below and during chapter 5, it is expected for them to be connected and discussed with the findings of this thesis:

- **Behaviorism** emphasizes on the learner's response to the stimulus and knowledge acquired is depicted on learner's behavior (Mödritscher, 2006; Young, 2003). According to behavioral psychology, students learn new skills based on their previously acquired knowledge (internal conditions of learning) and also receive specific learning outcomes derived by a designed set of instructions (external conditions of learning) (Gebremeskel et al., 2016). Hussain (2012) related behaviorism to the first edition of e-learning where the students could get the already available educational material online.
- **Cognitivist theory** thinks of the learner as a *processor* for the information, as learning is based on learner's brain and not his/her behavior (Hussain, 2012; Alzaghoul, 2012). As a theory, it is a successor to the behaviorism theory and adds the component of the *inner workings* in comparison to behaviorism (Downes, 2010).
- According to **constructivist theory**, learners try to make meaning of their experience (Hussain, 2012). Reality cannot be predicted and is something that is made up by humans, according to their own interaction with the surroundings. Humans *construct* their own concept, which then gets perceived in the human brain as the reality (Kundi, Nawaz, 2010; Alzaghoul, 2012). According to Philips et al. (2008), constructivist theory contributes to collaborative learning and then learning in digital environments becomes easier and effective.
- **Connectivism** is the theory connected the most to more recent technologies according to Hussain (2012) and was created after technology had already been

applied in education and new forms of learning had been introduced. On 2005, Siemens characterized connectivism as the *"a successor to behaviorism, cognitivism, and constructivism"* and it is considered the theory that is related the most to the new digital era.

It appears that learning theories' basic philosophies apply to technology-enhanced teaching methods and some of them can be more widely applied to it, and even adapt to the new era of teaching. The learning theories will be further discussed in relation to the changes that can happen in the educational system due to the possible introduction of IoT in it. The learning theories, as we know them now, might be reformed and new elements can be added on them, or there can even exist a creation of new ones.

2.2 Sweden and research on IoT

Even though teachers have been reluctant to integrate ICT tools in education, there has been some research in Sweden regarding IoT in schools. Two projects will be discussed below, one performed by Tieto, and the other by IoT hub skola. Furthermore, there will be a discussion about Sweden and ICT use in school as it has been occurred until now.

2.2.1 Tieto and Anderstorp Gymnasium

In 2018, Tieto ran a project about future classroom in collaboration with Skellefteå municipality and Anderstorp Gymnasium regarding IoT in school, and more specifically how it can be integrated in the presence registration procedure. Their investigation goals were time reduction, transfer of responsibility to students, data accuracy, focus increase, communication enhancement with parents.

Tieto mentioned that teachers are spending a big amount of time to monitor pupils' attendance and manual registration creates uncertainty for the students and can distract teachers from their main role. They tested two different presence registration methods (one with beacon technology and one with facial recognition) and then checked it in terms of feasibility, likeability, benefit and ethics/legal. Even though the project has mainly administrative-related functions, it showed pedagogical potential since an application that eases administrative functions can save time from teachers and give them the chance to invest this extra time to their students. According to the project's goal, it can make students more independent and focused and it can ease communication. In the conclusion part of the research, Tieto stated that suggestions need more research and also that the ethical part should be further discussed (Skellefteå Municipality, Anderstorp Gymnasium & Tieto, 2019).

2.2.2 IoT hubb skola

IoT hubb skola[2] project is a project that takes place during 2018-2021. The project owner is Kungsbacka municipality and RISE is the project manager. The project's main objective is to explain what IoT introduction can mean for school and invests on IoT, sensors and learning analytics.

Three reports have been written already. The first one, written by Patrik Hernwall and Robert Ramberg and published on January 2019 (*State-of-the-art kring undervisning och lärande*) is a literature review that described the current situation and potential introduction of IoT in schools. What proceeded from the review is that there is lack of research when it comes to IoT/sensors in school and most of the articles only examine potential use but do not analyze the potential educational value (Hernwall & Ramberg, 2019). On a second report published on April 2019, the authors Jacob Michelsen and Martin Johansson (researchers on RISE) discuss "*mapping and description of needs*" (*Kartläggning och beskrivning av behov*) and is about the teachers' needs regarding IoT. The main needs proceeded were the following: healthy and safe students, easier administration and logistics, better communication, pedagogical needs (feedback, speech time and attention) infrastructure problems, environmental issues. The third report written by Jan Hylén (2019) is about the integrity, security and legal part of the application of IoT in schools. The main concern stated was the safety of the data that can be collected by students with an IoT tool.

What IoT hub skola project has shown so far, is that teachers see administrative, pedagogical and other opportunities on IoT integration. However, more research is yet to be done about these pedagogical opportunities and the ethical and legal part has to be considered. This thesis will try to narrow this gap and will try to describe more pedagogically valued topics related to IoT.

2.2.3 Swedish education and ICT use

Information and Communication Technology tools are tools that are based on Information Technology, enriched with the telecommunications and computers elements ("Information and Communications technology," n.d.). ICT tools are very important for the educational system and they act both as *tools and objects of knowledge* (Bilyalova. 2017). In order for the IoT paradigm to be developed, advanced ICT tools must be used (Wang, 2014).

As documented in the new digitalizing strategy for school (Utbildningsdepartementet, 2017) the Swedish government aims to reach number one in the world regarding digitalization possibilities. School plays an important role on how the digitalization can affect the individuals and the society overall. This strategy intends to identify new solutions enabled by digitalization, with the intention to develop the most relevant. A concrete strategy will help to smooth differences that proceed from the fact that not all the kids have the same opportunities in technology access. The

[2] http://iothub.se/

strategy focuses on a high level of digital literacy among children and students, equal access and use, and research on digitization opportunities. Both the Swedish parliament and the committee of digitalization state that it is an essential for not only pupils but also for teachers to have a high level of familiarity with ICT tools since their wrong use would have a bad impact to students. Augmented stress and distraction are two challenges that the Parliament report notes (Riksdagen, 2016).

On a research performed by the European commission on ICT in education, Swedish teachers were proved to be the ones to worry the least in Europe that pressure for exam preparation may stop them from using ICT in class. On the contrary, a quite high percentage of them disagreed that ICT use could have a positive impact on teaching and learning procedure (European Schoolnet & University of Liege Psychology and Education, 2013). According to a survey performed by knowledge foundation at 2006, teachers didn't feel that much competence when it comes to ICT tools but they were more willing to integrate them in comparison to headmasters (CMA (Centrum för Marknadsanalys AB), 2004).

It is true that IoT integration holds promises for changes in the learning situation. IoT tools can make learning adapted to individual, it can be used as a teaching tool and can create new teaching methods and reform the existing ones. Since the whole teaching procedure might be reformed, learning theories might be reconsidered and students' learning outcome might be improved.

3. Methodology

The aim of this chapter is to present the research strategy, the research methodology, the data collection and analysis methods chosen for this thesis. Furthermore, alternative strategies and data collection methods are considered and the final choices are justified. On its initial stages, this thesis was conducted in collaboration with two other students from DSV (Bertilsson & Bodin, 2019) who were writing their thesis with the same overall topic (IoT and school). The main part of the collaboration took place during the first data collection phase (workshop). Teachers from schools throughout Sweden will participate in the project in order to express their views and concerns regarding the research problem.

3.1 Research Strategy

3.1.1 Grounded Theory

The research strategy which will be used for this thesis is grounded theory. Glaser and Strauss (1967) were the first to introduce the grounded theory approach in social research. The grounded theory strategy is used to generate theories rather than describe a phenomenon and focuses on connecting research theories to real-world situations (Glaser & Straus, 1967). This thesis is a small-scale research that describes humans' viewpoints on a topic. According to grounded theory, empirical research is held, and then, according to the data collected, general theories are created and generated (Johannesson & Perjons, 2014). The data in grounded theory has to be analyzed systematically and therefore produce new concepts and theories rather than speaking for themselves like they do in the ethnography strategy and (Denscombe, 2010, p.106-124). The results that were produced by this thesis cannot be considered theories, as they have not been tested in order to be generalized into being called *"theories".* However, their analysis proceeded by using grounded theory as a base.

A research strategy that could have also been chosen is surveys. Surveys are useful when a big number of people are needed to be asked about their actions, choices and thoughts. Survey participants are asked to answer the questionnaires from which data is derived and analyzed. The findings proceeded from this analysis are generalized (Johannesson & Perjons, 2014). They are also particularly good when a specific category of people is needed to be examined and the researcher knows beforehand all the important aspects of the topic examined. However, since the surveys are mainly applied in specific, relatively uncomplicated issues and since the specific topic of this thesis has not yet been examined and the aim of the whole project is to develop new theories that have not yet been recorded, surveys are inadequate. Furthermore, in a survey, the outliers and answers outside the pattern are omitted. According to Charmaz (2006, p. 81), grounded theory does not ignore data outside the pattern. On this research that uses grounded theory, no results will be skipped, since they can contribute to the developing of the theories, only the ones that might look inconsistent.

Case study is a less relevant research strategy choice, even though challenges and opportunities of a specific group will be explored and the Swedish educational

system could be considered a “case”. In this strategy, a specific object is used as a basis for generalization of a concept (Johannesson & Perjons, 2014). Case studies are used to describe relationships in a specific social setting, grounded theory produces new theories rather than explaining them. Nevertheless, since, in this current research, neither generalization for the school in Europe for example should be made, nor any comparison, it is irrelevant and unnecessary to choose case study as a research strategy (Denscombe, 2010, p 55). The aim is to construct new arguments, therefore, grounded theory is an appropriate strategy.

3.2 Data Collection Methods

3.2.1 Choices of methodology

Here is a diagram that describes the methodologies chosen for this thesis, the data flows and how each method produced material for the next one, or in the case of 3b phase, how this data validated the findings from the other methods.

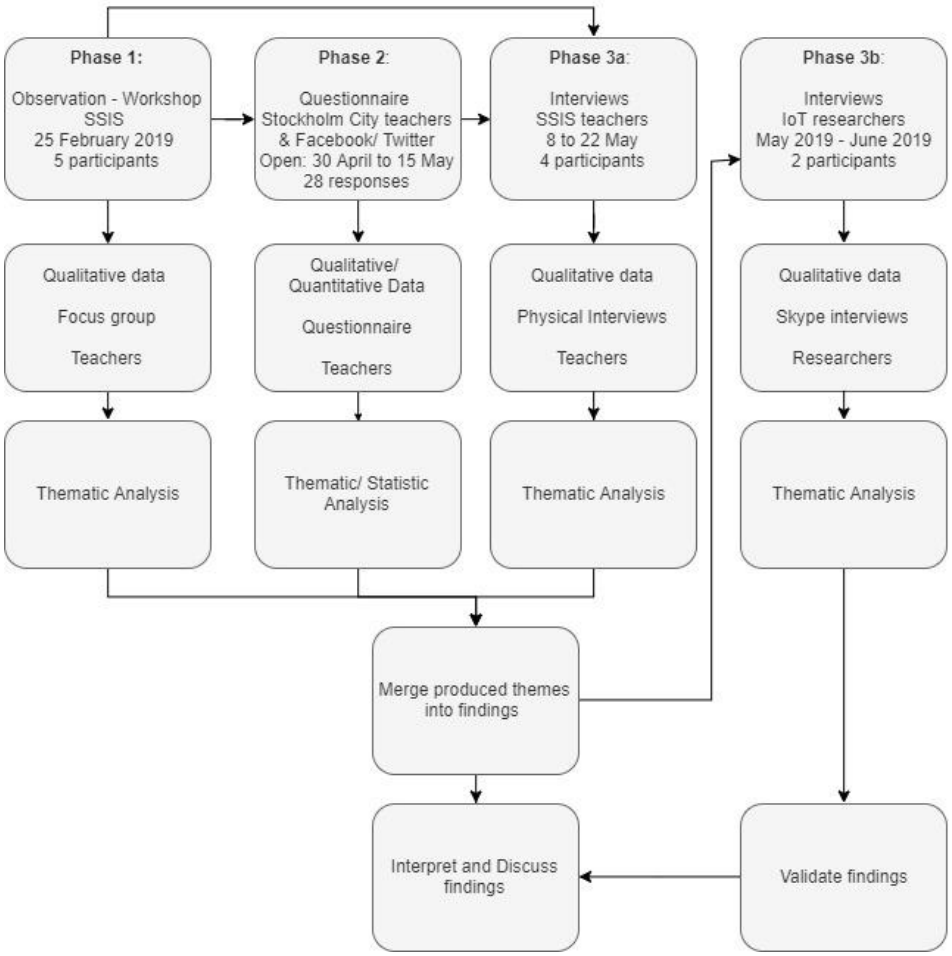

Figure 2 Methodology diagram

The data collection started with the observation of a workshop that gave an initial trigger to the author to get inspired on how to start with the main design of the data collection methods. This workshop was designed by the two fellow students mentioned earlier and the author participated as an observer. More details about the workshop will be given later on this chapter. Consequently, it seemed that the best option could have been a big number of interviews, since the study is based on empirical data, gathered from a specific group of people. Questionnaires were the second choice since they are also an appropriate means to gather empirical data and they were also used due to lack of data. This study is comprised of three data collection phases (see fig. 2). All three data collection methods that were used for this thesis are discussed below:

Observation: For the first phase of the data gathering, the author of the thesis participated in a workshop as an observer. The teachers in the workshop were a focus group. Focus group members share their viewpoints and also compare them to others' opinions. In a workshop organised by IEEE, NSF and Internet2 (2016), participants had the chance to express their concerns on how IoT can create innovation. They discussed how IoT can be applied by educators so that teaching becomes more effective (Aldowah, 2017). In order to examine teachers' views on ICT use in class and how it affects learning, both Erixon (2010) and Lindberg et al. (2017) created small focus groups of educators and performed interviews. Therefore, observation seemed like a good start for the data gathering of this research. Morgan (2006) suggested that a discussion between the members of a focus group leads to not only their bare opinions but also why they share this opinion. So rather than exclusively traditional interviews with teachers, a discussion of the focus group in the workshop would give more intuitive results (Morgan, 2006, p.121). For the current study, both focus group and interviews will be used.

Interviews and questionnaires: About the second phase: due to the aims and objective of this study, there were two options available when it comes to methodology choice: Interviews and Questionnaires. As Woolfolk, Davis & Pape (2006) suggested, a questionnaire on the teachers' belief could not be a valid option for self-evaluation since as Pajares (1992) said, "*beliefs cannot be directly observed or measured but must be inferred from what people say, intend, and do*" (Pajares, 1992, pp 314). On the other hand, interviews as a method gather many advantages. They are a more direct perspective and are more personal than a questionnaire. Even though the questionnaire can be spread more easily, interviews have a higher response rate since they are scheduled. Respondents in an interview might feel they participate more in the experiment than if they have to answer to a questionnaire. A semi-structured interview like the one that will be used for the current project can lead to answers that are easier to handle than answers from an open interview (Johannesson & Perjons, 2012, p.58; Denscombe, 2010, p 169-171, 192-194). It was decided that semi-structured interviews would be a good idea. Interviews with teachers from SSIS and with the writers of an IoT hubb skola report were held. Philips (2008) held semi-structured interviews with educators in order to examine their needs and level of satisfaction. The results were recorded in audio format and after a first analysis of the data, some follow-up questions emerged, so some teachers were interviewed again. In order to complement the

interviews and observations, an online questionnaire was designed and was sent to a bigger body of teachers. Fives & Buehl (2008) created a questionnaire to evaluate teachers' beliefs about teaching knowledge and ability. The methodology of this study is therefore a mixed methodology that consists of both quantitative (questionnaire) and qualitative results (interviews, questionnaire).

3.3 Participants and data collection strategy

The data collection happened in three phases as it is depicted in figure 2.

1st phase of data collection: The first part of the data collection took place at SSIS (Stockholm Science & Innovation School) during a workshop, organised by the two fellow students (Bertilsson & Bodin, 2019). The workshop's aim was a first discussion on the participants' opinion about how IoT could be integrated in school. The workshop's organizers gathered a team of 5 teachers and the workshop was planned for the 25th of February 2019 in SSIS premises. The workshop that lasted about an hour and the participants were teachers from various fields and of different sex and age (table1). The teachers first wrote down the challenges in school that have arisen from digitalization and then discussed about them with the whole team of participants. The meeting was recorded by two Dictaphone devices the organizers had, and then the transcriptions were given to the observer by the organizers.

The main points of the workshop were extracted and the data was then evaluated and along with the literature review, a first draft of a questionnaire was designed according to the findings. The draft was then sent to two teachers from SSIS for a test round. An improved version of it was created according to their comments and answers. Despite the fact that both the author and the supervisor acknowledged the need for a second test round, due to lack of time, the questionnaire had to be spread on its version as it was derived after only the first alternation.

2nd phase of data collection: Subsequently, according to what proceeded from the workshop, an online questionnaire was created via Google Forms and was sent to headmasters of schools of all levels in Stockholm city in order to be spread to teachers. In addition, the same questionnaire – with a different link and therefore a different database for answers–was posted on Facebook pages where Swedish teachers are members, and was also tweeted on Twitter with some relevant hashtags included (#lärare, #skolan, #frågeformulär, #iothubbskola #förskola, #gymnasium, #grundskola, #lärande, #pedagogik) that would communicate it to Swedish teachers more easily. Two different copies of the same questionnaire were created, and the answers have been kept in two different databases.

3rd phase of data collection: During the third phase of the data collectionf, the author arranged semi-structured interviews with teachers from SSIS. The author contacted SSIS teachers via email (the email addresses had been asked from them during the workshop) and arranged the first interview for early May. After the first interview took place, the first interviewee forwarded the interview invitation to some

of his colleagues and the invitation was spread more widely. In total, four teachers responded to the invitation and interviews were held during May 2019.

3.4 Data Analysis

The data from the workshop, the open type questions of the questionnaire and the interviews were analyzed with the thematic analysis form of analysis. Themes from all three analyses were compared and the main arguments about were created.

"*Thematic analysis is the process of identifying patterns or themes within qualitative data*" (Maguire & Delahunt, 2017, pp3352). Thematic analysis is a flexible method, proven to work with teaching and learning research. Thematic analysis aims to produce themes that are important and derive from the interview/questionnaire questions. Braun & Clarke (2006) mention two kind of themes that can be produced from a thematic analysis. The semantic and the latent. Semantic themes summarize the sayings without looking behind the words, whereas latent themes create hidden meanings, concepts and assumptions through the analysis. Braun & Clarke (2006) also distinguish two categories of analysis: an analysis that proceeds from the data (bottom-up) and one that proceeds from the research questions (top-down). In this thesis, the analysis proceeded from the research questions and the themes produced were latent.

Braun & Clarke suggested a six step guide for thematic analysis that was followed in this thesis (latent) as described below:

1. *Become familiar with the data:* all the workshop/questionnaire/interview data were transcribed and read. Notes were made and tables were created that summarized the main concepts.

2. *Generate initial codes:* initial codes were produced, and they were separated according to which question they were related to. The codes that were produced were open and not pre-set. The first code ideas were created after a thorough reading of the data gathered. No software was used for this purpose.

3. *Search for themes:* All the codes that fitted together were joined and themes were produced.

4. *Review themes:* the themes from step 3 are revised, modified, and all relevant to them data is gathered together. It was checked whether all the data assigned to the themes are properly assigned, and if all the themes are different from each other. At this point, some themes seemed to be similar or overlapped, so they were merged. Some other contained too much data, and they were broken into two separate themes.

5. *Define themes:* Final themes were created and connected to each other. Subthemes also were stated and all the relations between the different themes were finalized.

6. *Write-up:* A discussion on the findings was made.

The questionnaire responses were both qualitatively and quantitatively and thematic and statistical analysis was held to both kinds of data. The questionnaire that was sent to teachers from Stockholm city and was posted on Facebook and Twitter included some background questions and then some Likert scale questions. The Likert-scale questions of the questionnaire contained numerical values and therefore the responses were analyzed statistically and mean score values were calculated and the results were analyzed according to what it showed. The mean score (arithmetic average) for every answer was found in Microsoft Excel 2016. Supposedly the 5 responses (1-5) are evenly distributed, they can be considered as ratio data. According to Denscombe (2010, pp 248), mean value can be used with ratio data and is a measure of central tendency. It was evaluated as a description of a general trend that proceeds from the teachers' answers. An alternative way of describing the central tendency would have been the median value: "*exactly half the values are above the median and half the values are above the median*" (Denscombe, 2010, pp 249). The median shows the mid-point of a range, whereas the mean value shows the average value. The mean value is affected by any extreme values and the median is not. However, even though median is preferred for small data sets, it is safe to use mean to calculate the central tendency – mean value was preferred for this thesis, as it would show more detailed results-, since the number range is small and any extreme values are not really extreme and will not affect the real quality of the tendency.

The final codes proceeded by the thematic analysis and the statistical data were translated into semantic data and visualized. At the end of the process, the findings were stated and discussed (chapter 4) in relation to literature stated earlier (chapter 2). In chapter 5, these findings were further discussed.

3.4.1 Validation of findings

After the empirical data had been gathered with the 3 first phases, the author conducted two separate Skype interviews during late May/early June 2019 with the RISE researchers Martin Johansson and Jacob Michelsen, who wrote the report *Mapping and description of needs* for the IoT hub skola purposes (Johansson & Michelsen, 2019). The aim of these interviews was for the author to learn more about their experiences from the workshops performed for their report's purposes as well as the analysis of their data. The interviews were held after a preliminary analysis had been done on the data collected. Their answers were not analyzed to findings as they are described in chapter 4, but were rather used to frame the findings from the other methods and as a validation technique.

Data gathered from all sources was about opportunities and challenges proceeding from IoT integration and possible future changes for schools and teacher's role. Data from the workshops and interviews was qualitative data, and data from the questionnaire was both qualitative and quantitative. Table 1 above shows the code names per data collection method. In total, 5 teachers participated in the workshop (Teacher.i-Teacher.v), 28 teachers responded to the questionnaire (Teacher.1 to Teacher.28), 4 teachers from SSIS (Teacher.A, Teacher.B, Teacher.C, Teacher.D) and

2 researchers from the IoT hub skola project were interviewed (Martin Johansson, Jacob Michelsen).

Data collection method	Code name
Observation - Workshop	Teacher.i-Teacher.v
Questionnaire	Teacher.1-Teacher.28
Interviews	Teacher.A-Teacher.D

Table 1 Respondents' name coding

3.5 Research Ethics

Regarding the ethical part of the methodology: Consent forms were handed to all the participants where personal details of the author, purposes of the research as well as confidentiality settings, specification of the voluntary character of the participation and thanks messages were included in order to prevent any ethical implications.

The current research will follow the rules and guidelines regarding research in Sweden as they are stated in the "Good Research Practice" document and in the CODEX webpage (Vetenskapsrådet, 2017). These rules are applied in terms of handling of research material and the informants' anonymity and confidentiality, and also the relationship with the DSV students with whom the author collaborated. The teachers who participated in the workshop gave their consent by signing a form designed by the fellow students (it is attached in Appendix B: Informed consent form – SSIS Workshop). It was made clear by the organizers of the workshop that the teachers' discussion will be recorded by an audio recording machine. The teachers were informed that the audio will be kept in the organizers' computer for a year and that the only people who will have access to it will be the author of the current thesis and the organizers. As far as the questionnaire (Appendix C: Questionnaire – Swedish-Swedish version, Appendix D: Questionnaire - English-English version) is concerned, a consent form was included in the beginning of the document and the respondents had to check a box that they agree to continue as a prerequisite to continue to the questions. Regarding the interview process, a consent form was signed by the teachers that took part (Appendix E: Consent form (SSIS Interviews)).

3.6 Research quality

Research strategy: The quality of the data and the results as presented by the author is not an adequate factor to ensure credibility and validity of the results. The theories produced by the grounded theory can potentially have more credibility that the ones of the other methods, since they derive directly from the data and they match with

the facts and this matching is not forced (Denscombe, 2010, p. 118). As also mentioned earlier, on this research, the findings cannot be considered theories, since they haven't been tested. The strategy used is based on the grounded theory philosophy, in the sense that the findings are about new concepts that proceed from the analysis of empirical data and they are not generalized. However, Nowell, Norris, White & Moules (2017) explained that if the thematic analysis is not performed very thoroughly and effectively, it might hurt the credibility of the research process. In order to ensure credibility, the author collected data from three sources and two different types of data (qualitative and quantitative) (Tracy, 2010, p. 843) and also performed the interviews with Martin Johansson and Jacob Michelsen to validate the findings.

Literature choice: The research's quality is also ensured through the right choice of the literature used. The literature used is mainly literature published after 2010, that gives more recent, updated data in the field but not necessarily quite new, since it would mean that the journals lack assurance. Articles that were published in national and professional associations were preferred, since it means that they might have higher credits when it comes to quality, without this being absolute (Denscombe, 2010, p. 222)

Methods used: The questionnaire that was used for this thesis' purposes is a web-based questionnaire. Even though online questionnaires are cheaper and easier to spread as already mentioned, research quality is neither less nor significantly different than i.e. interviews (Denscombe, 2010, p.14). Reliability is about how consistent the results would be if the interviews/questionnaires would be repeated. When interviews are performed, it is difficult to have a high degree of reliability (Denscombe, 2010, p. 193, p.300). A way to ensure that data proceeding from a data collection method is reliable, the researcher can repeat the questionnaire/interviews. Since neither method was repeated, the data might lack reliability. In any case, since if the same interviews were to be repeated, the results might not be the same indeed (Denscombe, 2010, p.192), the reliability of interviews as a method can be never guaranteed.

Qualitative and Quantitative data: Qualitative and quantitative data might not be the same reliable, but the reliability is somehow balanced and cross-validated when results from both methods are combined and interpreted as a total (Denscombe, 2010, p. 237), as happened in this thesis. The quality of the quantitative data that was gathered from the questionnaire depends on the quality of the questions chosen (Denscombe, 2010, p. 269). The credibility of the research is also defined by the writing ability of the author to describe the results. This has to do mostly with the qualitative part of the analysis/data (Denscombe, p.210 p.296). Generally, generalizability can be more questionable when it comes to qualitative data than with quantitative data. Quantitative data is analyzed with statistical methods that gives more credits to the results. As far as objectivity is concerned, since the data, especially in the qualitative part of the research, are the product of interpretation as Denscombe says (Denscombe, 2010, p. 301), it cannot be completely uninfluenced by the author's perspective. Since the author of this thesis is not an experienced researcher and the sample of respondents is not big, credibility, generalizability and objectivity might not have been guaranteed.

Sampling: The sample selected for the questionnaire was semi-purposive. The biggest part of the questionnaire respondents as well as the teachers from SSIS and the IoT hub researchers were people already familiar with the IoT hub technology. That contributes to a higher research quality, as the respondents were able to give a better insight to the research problem (Denscombe, 2010, p.35). On this research, many of the respondents had similar educational level, and respondents were teachers from different fields and ages and both male and female, so the sample was diverse in terms of their personal background.

4. Findings

Thematic analysis was performed to each data collection method's empirical data set, and the themes were merged into new-main themes which the findings consist of.

- The themes that were produced by the thematic analysis for each phase are attached in Appendix A*: List of tables* (Table 10, Table 11, Table 12, Table 13 .
- The Likert-scale questions' means scores are also attached in Appendix A*: List of tables* (Table 6, Table 7, Table 8, Table 9).
- The name tag of the respondents according to the data collection method they participated in is described in Table 1 *Respondents' name coding*
-
- The respondents' profiles are analyzed in Appendix A*: List of tables* (Table 2, Table 3 , Table 4, Table 5).

The main argument that proceeded is that according to this thesis' teacher-respondents, possibilities in IoT integration can exist in learning in the sense that it can contribute to more personalized learning (4.1 below) and reform future school (4.2), even though there are some ethical concerns (4.3). The respondents are referred throughout chapter 4 by their tag name as explained according to table 1. In chapter 4.4, the findings that were produced from the interviews performed to RISE researchers are used as a validation method to support the concepts that would have been presented earlier (4.1-4.3).

The three main themes/concepts are illustrated below (see fig. 3):

Figure 3 Main themes proceeded from the analysis

4.1 Personalized learning

The personalized learning is the main finding emerged from the analysis. Personalized learning as a main theme consists of sub-themes as depicted in the diagram below:

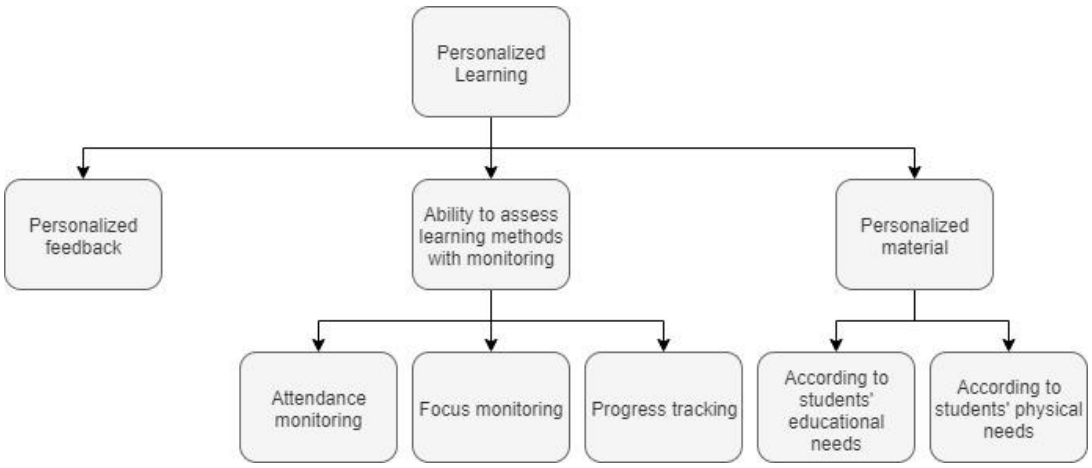

Figure 4 Personalized learning and sub-themes

4.1.1 Personalized feedback

Feedback is a very important feature in the educational system and it helps students go further with their knowledge and deepen their learning. Participants from the workshop, questionnaire and interviews characterized personalization of feedback as a big opportunity from IoT integration. The questionnaire respondents characterized personalized feedback as the most important opportunity by giving it the highest mean score in the corresponding Likert-scale question (4.37/5) (Table 9) . An IoT tool might be able to show what is happening with all the students, at the same time, even if they are not in the class (Teacher.C, Teacher.D). The big number of students in the classroom was mentioned by all SSIS teachers as an obstacle in giving individual feedback to students.

> *"It is difficult to interrupt if there is an ongoing discussion between me and students, it takes time and they have a short answer. And they have to wait, maybe they could interact or they could have caught the attention in other ways"* (Teacher.D, 22 May 2019).

Even though she is a big fan of technology, and she is ready to integrate anything, Teacher.B doubted whether an automated feedback tool could be more effective than her *"pen and paper"*, since she now has the chance to correct their assignments right in front of them, mark their mistakes with the green pen.

It is true then that IoT can create possibilities for easier feedback to the students (and also to teachers). Farhan et al. (2017) and Tan et al. (2018) designed IoT tools that included the feedback function.

4.1.2 Ability to assess learning methods with monitoring

Deep and successful learning outcome is not easy to be secured. Each person learn their own way and it would be important if successful methods could be tracked. A student can progress in the curriculum and achieve new knowledge, but it does not necessarily mean that this knowledge is deep or that it contributes to deep learning. Teacher.iii said that it is high time that people get to know *how* they learn rather than *what* they learn. Teacher.D said that they have already used video recordings in the classroom, but since they could only see themselves in the recording, they couldn't track how students reacted to their performance. It would therefore be interesting if teachers could track individual students' reaction to different practices and stimuli the teachers give in a specific moment.

Monitoring is something that takes place already at school and is important to ensure that the student is taking the best he/she can from school. What can be monitored is among others student's progress, his/her focus as well as other administrative concepts. However, no proper existing tools can perform the aforementioned functions, and it all lies to the teachers' good work. If this monitoring can be automated by sensors, data can be produced which, as it will be explained later, can boost students' motivation and if analyzed properly, more effective methods can be created and learning outcome will be improved. The teachers who responded to the questionnaire gave a low mean score (3.36/5) to the statement that IoT application can increase motivation (Table 8). However, teachers' beliefs and statements come to an agreement with what Reeve (2012) said about engagement and motivation. Meacham et al (2018) have discussed the same topic in their research and concluded that IoT can create better methods for teaching and therefore a better future for the education.

4.1.2.1 Focus monitoring

Each person's interests are different, and one person might be triggered by something that the other person might find irrelevant or boring. When students are exposed to different triggers, they might feel uninterested and not able to follow. A tracking method of attention/focus and loss of interest for each individual can therefore be considered important as it might be able to help teachers improve their methods. Even though the mean score for the corresponding question in the questionnaire was pretty low, -the respondents didn't believe IoT can improve students' focus (mean score 3/5) and they would be hesitant in integrating a tool that would measure brain activity to control focus (2.4/5) (Table 8, Table 9) - focus monitoring is a theme that cannot be skipped due to its strong presence in the rest of the data collection methods.

Teacher.C claimed that data proceeded by IoT tools could show whether focus is connected to true learning. Focus recall is a potential function of an IoT tool that seemed to be of many teachers' interest. According to the respondents, such a tool could either alert or even recall students when low focus is detected (Teacher.A, Teacher.B & Teacher.D). Teacher.D mentioned:

"*One of my classrooms is very noisy and maybe they can have a device with microphones detecting individual noise level. If one could present that to the whole class, […] perhaps they will want to get down the noise level*." (Teacher.D, 22 May 2019)

Even though IoT can improve focus if applied appropriately, it can get students distracted. Distraction was documented as a big challenge the teachers have to face. Some respondents were hesitant that IoT can help focus, possibly because such a tool might be one more tool that the students will want to play with when they are bored in the classroom (Teacher.B & Teacher.C).The parliament had also mentioned the distraction as a risk factor when ICT is being used in classroom (Riksdagen, 2016).

4.1.2.2 Progress monitoring

The learning outcome is often mainly measured through performance measuring. Since progress is personal, and learning also happens individually, if each single person's learning progress can be taken into consideration, personal learning can be enhanced.

According to Teacher.B, when students are able to see their good results in real time, when they can see their progress tracked and proved, they will feel more motivated and will keep performing well. According to Kullberg's research, in the majority, students got more motivated and their grades were improved when ICT tools were integrated in the lecture (Kullberg, 2011). Good feedback as well as high performances can mean higher levels of engagement to the teaching procedure (Bergdahl, Knutsson & Fors, 2018; Bergdahl, Nouri, Fors & Knutsson, 2019). Sclater (2014) had mentioned the connection between data gathering on students' performance and LA (Learning Analytics). Since Learning Analytics is about collecting, analyzing and measuring learning outcome in order to optimize it, by taking Sclater's suggestion into consideration, IoT can contribute to better learning outcome's optimization ("Learning Analytics", n.d.).

4.1.2.3 Attendance monitoring

The administrative part of their job seemed to be a big burden for teachers and takes a lot of their time. IoT can reduce this burden, and even though it might not look directly related to the pedagogical aspect, teachers felt IoT can help them save time even though for some of them having to learn how to use new tools might be time consuming (Teacher.iv). This time saved could be invested in i.e. creating better teaching planning (Teacher.B, Teacher.D).

Teacher.C stated that in the scenario of an automated presence registration, an automated warning could be given to the teacher if a specific student seems to be absent often. This warning can work as a warning that either something is wrong with the teacher's work or with the student's attitude. On their report, Tieto indeed proved that an automation on the attendance monitoring procedure would increase teachers' available time for teaching (Skellefteå Municipality, Anderstorp Gymnasium and Tieto, 2019). On their suggested system for teaching management, Tan et al. (2018) used RFID technology for attendance recording. This system had the ability to track what

time the students entered the classroom and therefore track absence or delay and even urge them be on time. If this administrative part can be enhanced via IoT, teachers might feel more secure that their students enjoy being in class.

To sum up, an IoT tool could track data that would depict teaching methods' effectiveness and help teachers improve them year to year. This effectiveness is expressed by the fact that the students might get more focused, their grades might get higher or that they will be eager to attend the lectures. However, data that is gathered through IoT tools needs a good analysis in order to produce useful findings (Teacher.A and Teacher.D); this comes to an agreement with what Gourlay and Oliver (2013) had said. This data not only can show good results on an individual learner level, but can also help schools.

4.1.3 Personalized material

Personalized learning cannot be achieved without personalized designed material. Apart from a material designed according to students' interests that might help them retain attention, a material that can address students' learning needs, according to their personal profile seems to be an important parameter for personalized learning.

Brown (2017) had created a headband that measured attention and helped teachers create teaching material accordingly. Teachers in the questionnaire gave a mean score of 4.07 when asked in a Likert-scale question whether IoT can create "Teaching adapted to individual student's level" and it was the third largest score observed after personalized feedback and air quality measuring (Table 9). Talking about neurodiverse students, Teacher.B claimed that IoT tools could be designed for them since right now they are part of a classroom that consists of 30 or more neurotypical students and they don't get the attention needed.

> *"One way of teaching might be beneficial for one group and not for another"* (Teacher.B, 14 May 2019).

This personalized material can be designed not only according to how the student learn, but also according to how the student feels when he/she learns.

4.1.3.1 Personalized material according to students' educational needs

According to the teachers' responses, it seemed as if IoT tools have the potential to create adapted material to students' educational needs. A high majority of the teachers claimed that if they know their students' needs, it might help them plan the course material the way they should, in order to achieve better results.

Some other suggestions made by the respondents include tools that would generate questions or topics that students would talk about and tools that could find relations and suggest proper groups of students according to their profile and characteristics (Teacher.B, Teacher.C, Teacher.16, and Teacher.17).

"Ability to have dynamic workgroups composed of AIs who know which students of different ages are on the same level" (Teacher.17, 10 May 2019)

Another interesting suggestion made by Ashman et al. (2014) is about the fact that when students engage to a project, the project material is the same for everybody even though a student might find difficulty on a specific phase of the project according to his/her individual level. A challenge in personalized learning is that the task should have the flexibility to be adapted to the individual learner's level on this specific stage.

Conclusively, an IoT tool can either track students' needs and collect data about them that can be handled by teachers, or create the personalized material itself, according to the students' personal profile. Even though the questionnaire respondents disagreed with it, Aldowah et al (2017) had claimed that teaching planning can be improved with IoT. In any case, there are implications it can be a tool that can help teachers save time and be more respondent to each pupil's individual needs.

4.1.3.2 Personalized material according to students' physical needs

In order for the students to be able to perform well, their physical needs must be also heard. It is important for the teachers to know that the teaching process make students physically comfortable. Each student has a unique body and his/her health system must be taken into consideration. A student must feel healthy during the lecture, in order to maximize his/her productivity. IoT tools include sensors that even in their simplest form, they can track physical activities. It was mentioned that well-fed students, with an appropriate blood sugar level, with normal stress levels, who breathe clean oxygen and have lectures in clean classrooms can perform better in class (Teacher.A, Teacher.B, Teacher.D). Teachers in the questionnaire ranked a potential IoT tool that will measure air quality as the second most important potential application (4.22/5) (Table 9). Teacher.A said:

"We had a problem with our ventilation the other day, and the students had an assignment and the results were lower than usual. The same happens with students who have Ramadan and do not eat" (Teacher.A, 15 May 2019).

In a similar manner, if data shows that a student has been siting for a long time, it might mean that he/she is tired and needs to get a break (Teacher.D). According to other researchers, better oxygen levels and temperature conditions not only create a more comfortable environment for the students, but also contribute to a school that is more sustainable and eco-friendly (Bagheri et al., 2016; Wang, 2014). Bagheri et al. (2016) suggested that the students themselves could give feedback on their level of comfort.

According to Tan et al. (2018), an IoT based system can relate teaching material to performances. This is quite relevant to Meacham's suggestion (2018) about educators being able to solve students' issues in real time, the moment they come up because of any specific teaching methods applied.

4.2 Future Schools-How school can be reformed

This is not a main theme produced by the analysis of the data gathered and it will not be investigated in depth. However, trying to answer the research question as to how IoT can change conditions for learning, it seemed of interest to present the changes IoT can bring to teachers' and students' role as well as to the school system.

All the suggestions made by Bottino (2003) as key aspects for school's reform were mentioned by the teachers on this thesis. It can mean that their perspective towards IoT shows signs and indications of how school can reform. The respondents however have agreed about the gradual integration of IoT tools (small steps and integration of smaller applications first) (Teacher.B, Teacher.C) in order for the school to be reformed more efficiently. A potential school reform consists of a change in teachers' and student's role and in the school system (see fig. 5):

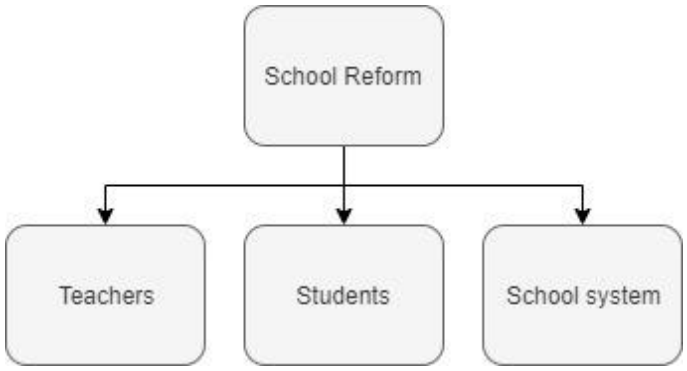

Figure 5 School reform sub-themes

4.2.1 How teachers will change

The reform that will take place in schools might mean a change on the teacher's role. According to the respondents, the teacher's role can differ from being a supervisor/ moderator to coaching and supportive. In any case, the teachers agreed that the teacher of the future should be a person with higher technological competence which will be used to support his/her role. Teachers are afraid that their role might change, and it was expressed that they might become lazier since they will have to deal with less tasks. There are those who believe that the teacher's role will be quite the same in the future, since no computer can replace their role and one specifically stated the following:

> "*…Just as it is today. I think it's hard to force new technology. There needs to be security, both for teachers and students. New technology can easily create concerns and ambiguities."* (Teacher.13, 10 May 2019)

Sheryl Nussbaum-Beach, an education expert and CEO of Powerful Learning Practice organization, Practice has said, *"Teachers will not be replaced by technology, but teachers who don't use technology will be replaced by those who do"* (Nussbaum-Beach, 2008).

4.2.2 Students' position and expected improvements

The need for higher knowledge demands was expressed, since it was mentioned that education has changed since the past, and according to Teacher.A and Teacher.C, the knowledge levels are lower, even though kids know better how to handle technological tools, but especially those related to their personal interests. Students technological skills must be also improved since as Bergdahl, Nouri and Fors (2019) had mentioned, high technologically skilled students can show higher engagement.

Changes might happen to both students' and teachers' roles, and they can possibly contribute to new ways of communication and collaboration between them. Teacher-student, Student-Student, Teacher-teacher collaboration and interaction is problematic (Teacher.C) but can be enhanced with IoT. This was a need that had been mapped by the teachers who had participated in the workshops for the IoT hub skola report (Michelsen & Johansson, 2019) and the need for improvement in teacher-parent's communication is also described in Tieto's report (Skellefteå Municipality, Anderstorp Gymnasium and Tieto, 2019). Bottino (2003) had also suggested that improved teachers' cooperation would contribute to a better school system.

4.2.3 How school system can change

School system can consider data that has proceeded from IoT tools and connects good teaching methods with successful learning and can use them for the school's improvement. Schools have to have their own improvement as their main objective:

> *"Every school should have the demand to work on the abilities of the students that come in the school, so that they have higher abilities when they leave school. If IoT can somewhere, somehow teach the school system how to work with students, this would be very good for the society"* (Teacher.C, 15 May 2019).

Gonzalez et al. (2008) and Gómez et al, (2013) had claimed that IoT can create more innovative teaching methods. The teachers seemed to be interested in the possibility of distant learning. Teaching in the future might hopefully take place distantly, and students won't have to attend physically the lecture. This is an opportunity that by now is not allowed according to the already existing law. Students in Sweden are not allowed to be homeschooled and Robbit [3]together with AV1[4] are first attempts that integrate sensors and help students who, due to illness in this case, cannot attend school physically. If Robbit is decided to be integrated, the law will have to be modified. This tool can offer possibilities for new practices and qualities and offer new opportunities to students with specific educational needs.

[3] https://robbit.se/en/

[4] https://www.noisolation.com/uk/av1/

4.3 Ethical concerns

According to the teachers who responded to the questionnaire, the biggest problems of IoT integration are related to personal integrity and ethical aspects. The GDPR law was also mentioned as a potential issue, and a general fear that the students might get controlled and their personal integrity might be violated came up. The fact that the data might be handled by other people than the teachers creates challenging ethical questions. A teacher mentioned:

> *"We get a Mass Monitoring School à la 1984"* (probably meant George Orwell's book, 1984). (Teacher.22, 1 May 2019)

SSIS teachers were much more tolerant to privacy issues than the ones who had replied to the questionnaire. SSIS is an innovative school, that has already tried new tools and technologies, students are already familiar with their teachers i.e. video recording them during the classroom (Teacher.A, Teacher.B, Teacher.D). Nevertheless, students have always signed and given their consent. Teacher.C claimed that students might feel controlled in case their attention to the lecture was about to get measured.

According to Hylén (2019), even though consent must always be given, nobody can be ever sure where data in servers can end up. He also added that if for example random bracelets with sensors to measure stress levels would be handed to the students anonymously, it would be more ethically and legally acceptable than using face-recognition. However, the data produced, even though it would give a useful meaning about students' condition in class, it wouldn't be of the same importance as data that measures performance and is connected to the individual student's profile as mentioned above (Hylén, 2019).

Tieto had mentioned in its report the need for a further discussion when it comes to ethical aspects of its project (Skellefteå Municipality, Anderstorp Gymnasium and Tieto, 2019). After controlling the procedure of the project, the Swedish data inspectorate imposed a penalty of 200.000 Swedish crowns to Skellefteå high school for violating multiple legal articles that concern personal data (regarding the face recognition application) and for not consulting the inspectorate prior to the procedure (Datainspektionen, 2019). Therefore, it seems like more attention should indeed be paid to the personal data part.

Reeve (2012) suggested than in order to increase students' motivation, teachers can use a tool that integrates *"intentional monitoring and enhancement of engagement"*. However, he added that controlling classrooms would undermine students' engagement and the results in learning might be worse. This comes to an agreement with the concern the teachers had regarding control impact and the part about the ethical concerns that participants had.

On their suggested system, Tan et al. (2018) integrated RFID as a tool to record student's behavior and evaluate their respond during the lecture. Tags like "bad attitude", "sleep" and "play game" were used and each one of them had its own RFID card that the teacher could scan in order to register the students' behavior during the lecture. Their system spontaneously and randomly produced questions that had to be

answered by the students in order for them to prove if they were paying attention, otherwise to recall focus (Tan et al., 2018). This looks like a strict approach that the teachers who are against control would not likely adopt.

Use of IoT for focus recall was questioned, as, throughout the data gathering, there were those who were in favor of IoT for such an application, and those who were pessimistic or maybe unaware how sensors could help students get more concentrated. The ones that have been in favor claim that an IoT can be used as a "reminder" to the student to recall focus and attention. The ones that are against might feel that it forces students to be concentrated and removes some of their personal freedom. In this case, the theme of ethical concern can either be translated as a concern related to the behavior the teachers expect to have towards their students. In addition to what has proceeded in the theme regarding future teacher's role, it can be assumed that teachers want to adopt a role that doesn't include control but to create inspiration to the students.

4.4 Complementary themes

These are two more themes that proceeded from the analysis but are not related to the previous main concepts. The reason why this chapter is here is because these themes are important to support arguments presented later in this thesis.

4.4.1 IoT as a teaching tool

An interesting point is the use of IoT as a teaching tool. Suggestions made were IoT for experiments, laboratory work, and alternative methods for math teaching (Teacher.C, Teacher.D and Teacher.19). A similar suggestion had been made in university of Gordoba, in Colombia, where an IoT prototype that integrated NFC and QR code technology was created to help students learn the different parts of a computer by scanning them. The results showed that it actually helped students improve their learning income (Gómez et al., 2013). Stuikus et al (2018) described a possible application of the IoT in STEM education. They suggested that sensors can be used in classroom to measure humidity and temperature conditions for plants in classrooms during STEM lectures. This suggestion combines the IoT as a teaching tool and the sensors that can measure environmental conditions (Stuikus et al., 2018).

4.4.2 Complementary challenges

Other challenges are related to high cost, bad infrastructure, low teachers' ICT competence, students' dependency on technology, the fact that students take "shortcuts" in order to achieve knowledge and the big volume of information provided to the students (Teacher.A, Teacher.B, Teacher.13). Since IoT integration can be considered controversial in a way, it looks like it needs time for it to be integrated in classroom and it must take place gradually, and teachers don't want to be forced to introduce it.

4.5 Validation of the findings

4.5.1 Validation: Personalized learning

According to Jacob Michelsen and Martin Johannsson, IoT can create adapted learning experience, help teachers check their students' progress and improve teachers' performance.

4.5.1.1 Validation: Personalized feedback

Michelsen & Johansson (2019) had pointed out the possibility for new feedback methods, automated ones, something that can lead to pedagogical benefits.

4.5.2 Validation: Ability to assess learning methods with monitoring

According to Jacob Michelsen, the analysis of data tracked by IoT tools and related to students' performances and teachers' practices might frame a predictive analysis that will train systems to predict students' success as well as train schools how to ensure true learning and good grades to students according to previous successful techniques.

4.5.2.1 Validation: Progress monitoring

Jacob Michelsen claimed that IoT can help teachers control their students more effectively.

4.5.2.2 Validation: Attendance monitoring

Martin Johansson stated that there are pedagogical opportunities in the whole administrative part. Since much time is spent in the administrative and not all teachers can combine the two parts successfully, a tool that would take over this administrative burden

4.5.3 Validation: Personalized material according to students' needs

4.5.3.1 Validation: Personalized material according to students' physical needs

Martin Johansson claimed that a clean classroom can contribute to good performances.

4.5.4 Validation: School reform

4.5.4.1 Validation: Students

Jacob Michelsen suggested that the pupils should be included in the dialogue for IoT integration in school.

4.5.5 Validation: IoT as a teaching tool

Martin Johansson suggested that a tool that can track oxygen levels in classroom can be used as a teaching tool also in environmental courses.

5. Discussion

Technological tools integration in education is not a procedure that can take place without any background change in educational strategies. *"Pedagogical issues have often been overshadowed by developments in the technology"* (Harper, 2003, p19). Bottino (2003) claimed that policies should change from *"technology push"* to *"demand pull".* That means that technology is not supposed to be forced to be applied in school due to technology availability, but it is needed due to its pedagogical opportunities. In order to see how IoT can change school and how it can be integrated, one must look first at the pedagogical problems and opportunities. This is what this thesis addresses. The main opportunity proceeded by this thesis' analysis is the potential of personalized learning.

In this chapter, it will be further discussed how the personalized learning achieved by IoT integration can change the way teachers perform their role (learning theories – chapter 5.1), how it can help students succeed on their task (higher motivation, engagement and learning outcome – chapter 5.2) and how it will contribute to school's transformation into its future "smart" version (chapter 5.3). Furthermore, the ethical implications proceeded by this personalization will be further discussed (chapter 5.4). This discussion will take place according to the findings in chapter 4 and literature already presented in chapter 2.

5.1 Personalized learning and learning theories

The four basic learning theories will be discussed and they will be considered in relation to technology-enhanced learning and to the implications made by the respondents. According to the literature and data analysis presented earlier, sensors and IoT integration can bring changes to the ways people learn, and therefore modify the already existing learning theories and why not, create new ones. That means that teachers will have to adapt their basic philosophy to technological innovations and therefore endorse new characteristics that can reside in already existing learning theories.

None of the teachers interviewed stated that they use a specific learning theory guideline while teaching. However, their personal methods, probably an instinct-based procedure, might be aligned with some characteristics of some already defined theories. In addition, their suggestions and "dreams" regarding a future education model that integrates more new technologies like IoT, might reform anew these theories.

The four basic learning theories are depicted in figure 6, including a brief description each:

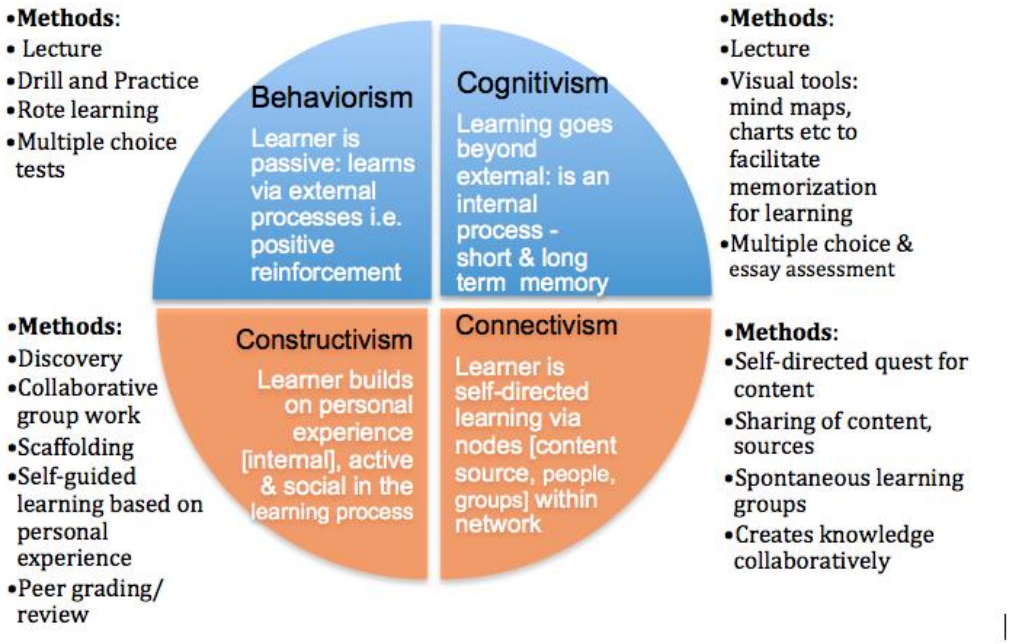

Figure 6 Four basic Learning theories (Morisson, 2013)

- Behaviorism and Cognitivism are teacher-centered theories
- Constructivism and connectivism are student centered learning theories

The four learning theories will be now discussed further according to the findings:

- **Behaviorism**: Gebremeskel et al. (2016) claimed that ICT use has become fundamental in education and integration of ICT tools in the learning process leads to a change on student's behavior. "*In behavioral psychology, reinforcement is a consequence applied that will strengthen an organism's future behavior whenever that behavior is preceded by a specific antecedent stimulus"* ("Behaviorism", n.d.). This can be related to the function of a potential IoT tool that recalls focus as this was described earlier by the respondents. That means that teaching with IoT tools that can recall focus or increase motivation, can be associated to teaching methods that are based on behaviorism theories.
- **Cognitivism:** According to cognitivist theory, learning outcome resides in human brain rather than behavior (Hussain, 2012; Alzaghoul, 2012). Downes (2010) said that what makes it differ from behaviorism is the fact that during cognitivist theory, learners are subject to some *"inner workings"* that can define the way they learn. The results mentioned in the previous learning theory included functions where students' focus was recalled. If the inner working feature was to be added, it could be said that cognitivist theory could be associated with the connection between the results of the attention tracking to the students' performances. Also, it can be connected to the tools that could show the stimuli and brain reaction relationship.

- **Constructivist theory**: In constructivist theory, reality is created by the learner and is triggered by the perceived reality (Kundi, Nawaz, 2010; Alzaghoul, 2012. Learner is the main person and the teacher is only a facilitator (and both of them are involved in the educational process) ("Constructivism theory", n.d.). This characteristic of the constructivism theory can be related to the suggestion the teachers made about measuring students' attention and focus to different stimuli when teachers present some new material. However, it might happen in a different way than in the cognitivist theory. Therefore, even though constructivism is a theory that is student-centered, and the concept described above is a typical teacher-centered one, they are connected in the context where the students provide their own "feedback" to the educator by showing their interest to what they are being taught. In addition, the automated question generator according to the already acquired students' learning outcome, borrows the constructivism's theory feature according to which students base their future knowledge to their already existed reality and knowledge. In addition, the creation of appropriate groups according to their level is a suggestion made by the respondents and applies to the constructivist theory's attributes.
- **Connectivism:** The key factor that leads to knowledge according to connectivism is that the students can address to non-human appliances such as Machine learning, Artificial Intelligence and 3D interaction in order to acquire knowledge (Hussain, 2012; Siemens, 2005). The potential use of IoT as a teaching tool as it was suggested in this thesis is an application of the connectivism in the educational process (not connected to the personalized learning, but still a theme produced by the analysis of the empirical data). However, as the teachers suggested, searching online for information can cause a problem to students since it might mean both that they might follow shortcuts and not really develop a critical thinking and that they might be subject to an information overload. By this, one can assume that the teachers interviewed for this thesis and addressed these problems, would not embrace connectivism characteristics.

Except for the changes personalized learning can bring to how teachers perform their role, they can also bring changes to how students learn. These changes are further discussed in the following chapter in relation to motivation and engagement.

5.2 Personalized learning and higher quality learning

In this part, the implications of personalized learning will be discussed in comparison to motivation increase and according to SDT theory as it was expressed by Reeve (2012). According to Reeve (2012) and the SDT theory, increased motivation can mean increased engagement to a topic and engagement can mean increased attention, effort and interest. If a student is engaged to what he/she is being taught, the learning results can become better. Personalized learning with IoT tools can give the student the opportunity to see his/her good results in relation to a higher focus and

attention, better health conditions and good discipline. If these good results can be returned to the student, they can keep him/her more motivated.

Motivation is an important feature in the learning process and takes place on an individual level and is personal. Reeve (2012) suggested five smaller theories of the SDT model, according to which motivation can be increased. Motivation was included as an important outcome on almost all subthemes of personalized learning mentioned in chapter 4. If these theories can be applied to each student through IoT, it means that personal motivation can be increased and therefore personalized learning of higher quality can be achieved.

According to teachers' proposals:

- IoT tools can provide autonomy to students, since they can work more independently and with material designed according to their needs. Competence can be raised if IoT is to be used as a teaching tool. Relatedness is about good relationships between students. It was indeed suggested by the respondents that learning can become more interactive and IoT might contribute to good relationships amongst students, however, since IoT tools can make them work more independently, it might undermine them (**Basic needs theory**).
- The fact that IoT can produce enjoyable methods of teaching and learning has indeed been introduced throughout the analysis. Since, in the case of IoT, teaching methods and material are personalized to the students' needs and interests, it means that teaching procedure might become more enjoyable and indeed make them more motivated **(Organismic integration theory**).
- As mentioned earlier, good learning outcome is often measured through grades and performance measuring. On this analysis, good performance was discussed in its relationship to personalized learning. When a student can assess the way they learn and can have better progress tracking through IoT, they can achieve higher grades. Good performances can document a good work done by the student, and motivate them to keep up with it (**Goal contents theory**).
- However, reward should not only be given through grades. Personalized feedback and reward in real time gives the students the chance to correct their mistakes and also feel confident and motivated with what they have already learnt (**Cognitive evaluation theory)**.
- Students can work distantly and independently if IoT tools are to be integrated. That can mean that in case a student's personal life condition prevents him/her from attending school physically or from being able to cooperate successfully with his/her students when in person, IoT can give him/her the opportunity to work successfully even remotely. (Ryan & Deci, 2002; Vansteenkiste, Niemiec, & Soenens, 2010; Reeve, 2012) (**Causality orientations theory**)

From what was stated above, one can say that the implications made by the respondents of this thesis fulfil the five theories of Reeve (2012). Therefore, these implications regarding personalized learning can be interpreted as implications concerning higher motivation -as this was defined by Reeve (2012)-. Higher motivation

can create higher engagement levels. In a similar manner, the suggestions made by the teachers can contribute to this motivation increase, and the IoT-based tools created according to these suggestions can realize their vision for a more personalized learning and also accomplish new levels of engagement. Some examples of tools that can be created and are connected to personalized learning might be the following:

- Attention and concentration level tracking tools (**Behavioral Engagement**).
- Tools that measure stress, oxygen levels, heartbeat etc. (**Emotional Engagement**)
- Automated reward-giving tools, that encourage student to continue their good job (**Cognitive Engagement**)
- Tools that track students' reactions to different stimuli and therefore give them the chance to assess how they learned (**Agentic Engagement**)

Reeve suggested that teachers can possibly introduce 1) *autonomy-supportive motivating style* toward their students and 2*) intentional monitoring and enhancement of engagement* (Reeve, 2012). The first implication can be interpreted in terms of IoT as a tool that functions autonomously and gives personalized motivation to the student. The second implication is difficult to achieve according to Reeve. The first suggested tool is similar to the potential expressed by the teachers concerning focus and progress tracking. However, regarding the second tool, Reeve's objection comes indeed to an agreement with the teachers' concern about tracking devices and ethical concerns.

Therefore, if SDT model is to be followed, one can say that many of the implications proposed by the teachers on this study are related to the motivation theories and engagement aspects. That means that IoT tools potential integration, as suggested on this thesis, can contribute to a higher students' motivation and engagement. When students' motivation is increased, the learning environment becomes more gainful for them.

5.3 Personalized learning and Smart School

According to the informants' suggestions, IoT has the possibility to transform school. IoT integration will enhance distant learning, teachers will have less administrative responsibilities and more time for their students, and school system can be improved if data gathered from students are to be exploited in a useful manner. Sari et al. (2017) discussed about IoT integration and the possible creation of a smart campus infrastructure in a university. The three elements that the smart campus consist of are e-learning, personalized learning and virtual classroom.

Personalized learning is the main implication proceeding from this thesis; the other two elements were also indicated and were actually connected with each other and were considered as part of the personalized learning as it was described in this thesis. Sari et al. stated the **e-learning** as the first feature of a smart university. Teaching material that exists online is a prerequisite and fundamental for teaching with IoT. As discussed above, teaching material is designed according to students' needs -educational and physical-, and is available online and is spread through network since this is how IoT works. This leads to the third feature of a smart school, the **virtual**

classroom. A high demand for distant learning was stated by the informants; the teachers want to have the opportunity to perform their role distantly, as long as they can have access to their students' activity. Sensors and IoT can help them towards this direction and it would be beneficial for them to be able to help their students without interacting in person necessarily. Robbit and AV1 are already existing robots that might be a first step to a virtual classroom in Sweden.

Therefore, according to implications made by Sari et al. (2017) and combined to the findings of this thesis, it can be assumed that the teachers' perspective could be interpreted as a vision for creation of a smart school. Maybe it is high time for the smart technology to enter education.

5.4 Personalized learning and ethical concerns

According to Ashman et al. (2014) –and this comes to a complete agreement with this thesis' findings- even though personalization on technology-enhanced methods of learning can bring many benefits, it can bring ethical implications. The findings of this thesis will be discussed in connection to Ashman et al.'s (2014) suggestions:

Firstly, personalization cannot happen without data gathering, so data privacy is violated since it is questioned who controls and owns this data. This concern has already been mentioned earlier in this thesis and has also been expressed by Hylén (2019). Even if a school is supposedly keeping the data on its own servers, these servers are provided by external companies that can hypothetically have access to this data. The reason why it is difficult for the privacy to be defended, is that first, legislation already existed is different across countries and second, it is difficult to define what personal data is (Ashman et al., 2014). For example, GDPR is only applied throughout Europe. However, even if data is a product of consent, there can be security breaches that might put data's privacy in danger.

Secondly, the data gathered by an IoT tool can be used to show inferences about the person's individual condition. On the one hand, if the IoT tool has not been designed properly, the results won't be accurate indeed. On the other hand, it can mean that if for example an IoT tool can track heartbeat in order to measure stress levels, it might infer that the person tracked has augmented stress. However, in reality, it can mean that the person is sick and has fever for example. That means that this data is not transparent and might not be even accurate. Since data tracked from a person can create a personal profile, it can even mean that a student's personal record can be used against him/her. In addition, if the student is not able to have the control of his/her personalized profile, they might feel powerless and it comes to a contradiction with human-interaction rules, according to which users must feel in control of their actions (Ashman et al., 2014).

Finally, it is stated on this thesis that IoT-based learning can give the opportunity for more students to study distantly. However, according to Ashman et al. (2014), it can be doubtful whether the quality of teaching and learning, even though personalized, can stay the same, since education won't be controlled by a human in the

same degree. In cases of university level, when learners can work completely independently, communication and social relationships might disappear. But since this thesis addresses young learners' education, the teachers doubted that their role will be extinct and they even considered communication and collaboration as opportunities from IoT-enhanced learning. So, even though lack of human monitoring would be a big social implication, it would not be as dangerous on lower level students, since it is doubtful that under-aged students could work with no human monitoring. Nonetheless, no one knows what the future promises.

That means that according to Ashman et al. (2014) data privacy, wrong inferences from data and doubtful technologies are ethical questions regarding personalized education. The social implications mentioned in the same article are the fact that a personalized material might make the students stay in their comfort zone and also that the student might have to work alone and the communication factor might get lost and human control lack can have bad impact on learning. On the other hand, since it is more possible that sensors can give better tracking of students' needs than any other ICT tool, and also since this thesis is about learners, the social implications are less here than in any other case of an ICT tool.

Consequently, appropriately integrated IoT tools can lead to changes in the way students learn, it can modify the methods educators use to teach, it can increase pupils' motivation and engagement and can contribute to smart school's realization. However, personalized learning proceeded by IoT use can create social and ethical implications.

6. Conclusion

6.1 Answer to research question

The research question set for this thesis was answered after the analysis of the empirical, gathered data. The answers is stated below:

RQ: *From a teacher perspective, how can IoT change the conditions for learning in formal education?*

Teachers who participated as informants on this thesis concluded that IoT have the potential to offer personalized learning to students and reform school even though there might be ethical concerns regarding its use. Figure 2 described the main proceedings. These are:

- **Personalized learning**

The main change IoT can bring is the personalized learning. It consists of different sub-themes that are shown in the picture and further explained below.

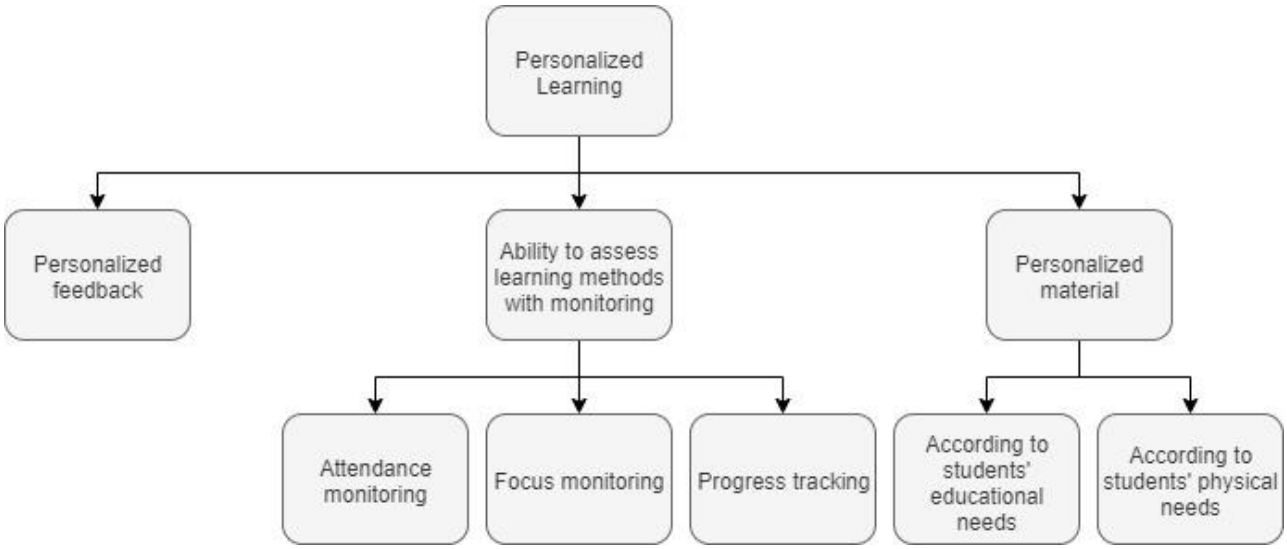

Figure 3 Figure 4 Personalized learning and sub-themes

With IoT, students can get feedback on their work, possibly automated and in real time. Furthermore, by providing data concerning their focus and performances, they can assess the methods by which they have gained new knowledge and help teachers create better teaching methods in the future. Last, it is important for the students to have material according to their educational needs and IoT can help towards this direction. In order for the personalized material to be designed, there must exist an accurate tracking of student's already acquired knowledge and educational profile as well as their physical needs. This way, every student learns what they should learn according to their profile, their needs and their weaknesses.

- **School Reform**

The data gathered from sensors might be used to increase students' motivation and train the school systems how to be more effective and predict success. The teachers hope for a school where education can take place everywhere. Education can be distant, and more interactive. In their great majority, all respondents look forward to a new educational era, where more technology will exist in schools and teachers will be more willing and enthusiastic to use it. However, since the administrative burden will be also reduced, and many of the teachers' main tasks will be replaced by computers, there has been a fear that the teachers' role will change and some others claimed that no matter how much things are going to change, the teacher's role is irreplaceable.

- **Ethical Concerns**

However, not all teachers agreed that everything about IoT will be successful and effective. There have been concerns regarding privacy issues when it comes to attention tracking or eye-tracking since it has to do with sensitive personal data of students, that no one can know where this data can end up and who might have access to the servers it is kept.

6.2 Limitations of the study

This study has some limitations that are discussed below:

6.2.1 Credibility

This study's credibility might have been affected by various factors. The credibility of the theories produced by the current thesis are judged by the following keys: Validity, Reliability, Generalizability and Objectivity. (Denscombe, 2010, p.298)

- **Validity**: Since the data gathered is empirical and are not of a factual nature (Denscombe, 2010, p 188), it cannot be crosschecked or validated. Luckily, the author didn't notice any cases where data might have been inconsistent among the different answers of the same questionnaire (for example someone that in half of the answers looks against the use of IoT but then suddenly gives written answers that show an enthusiasm toward IoT). In that case, the whole response would have been deleted. Due to the fact that half of the answers that produced the results were expressed written, and no clarifications could have been made, there can be some misinterpretation when analyzed. Denscombe (2010, p 189) suggests that a way to double check the validity of the data gathered is for the researcher to send the transcription of i.e. an interview to the respondent, so that he/she ensures that whatever has been written was what they meant. This method was not followed during this thesis due to time shortage and this can have a negative impact to the study's validity. However, themes were tried to be produced from more than one interview transcriptions, something that shows that the main ideas are shared

opinions of a bigger group of people and not individual, specific viewpoints (Denscombe, 2010, p.190).

According to Martin Johansson, the teachers who participated in their workshops seemed to have a problem to acknowledge their real problems and tell them out. It is a sensitive subject to discuss, and maybe some of them didn't want to speak out about their real beliefs and issues. Some might have confused IoT with digitalization, and since there are no good examples to describe it, it is not easy to imagine a tool that you haven't seen or used and even describe benefits or implications.

- **Reliability:** Since for the current thesis the author herself was the main research tool, the reliability of the research's results can be doubted if someone considers that the results could have been different if a different person was to conduct the interviews for example.

According to Jacob Michelsen, the time given for them in the workshops/interviews/ questionnaires was limited and their participation might have been "forced", so maybe the answers might not have been real or representative.

As for the observation part, even though the author was again the main research instrument, the data in the workshop case was recorded and analyzed after the workshop (it was not only based on the notes made the day of the workshop) and the author's findings were cross-checked with the findings of the fellow students-researchers who organized the workshop. Nevertheless, the author's inexperience concerning the formulation of the questionnaire might have affected its findings. A more experienced researcher might have been able to form questions that can produce more relevant results. The author's inexperience concerning performing interviews and leading discussions that might proceed from interview sayings might have also affected the findings.

- **Generalizability:** In a small-scale research like this thesis, the term generalizability term can be altered to the one of transferability. Denscombe (2010, p.301) argues about transferability: "*This is an imaginative process in which the reader of the research uses information about the particular instance that has been studied to arrive at a judgment about how far it would apply to other comparable instances*". The results that proceeded from the observation cannot be generalized and only concern a small team of people that participated in it. However, for this study, the author used them to go further in the research and come up with ideas about questions and discussions for the next applied research methods (Denscombe, 2010, p.214).

According to Martin Johansson, the formulation of the groups in the workshops might have been problematic or unsuccessful. People don't feel the same comfort to express themselves with anyone in their surroundings. A different formulation of groups might have produced deeper results. Also, the relatively small number of participants in both the questionnaire and interviews might be a problem for the transferability of this research. However, the suggestions are just indicators for future integration.

- **Objectivity:** This research can be considered objective in the sense the author was fair during the procedures of data collection, data analysis and findings and was not affected by any personal biases. Even though qualitative data is more prone to lower objectivity levels according to Denscombe (2010), all data was taken into consideration, even the one which did not look like it fitted with the rest (p.301). In any case, this research is about the respondents' viewpoint, so objectivity is not a factor to be taken into consideration during the data collection and evaluation but rather during the analysis. Data was analyzed with an open mind and alternative interpretations were given where possible in order for the result to be more objective (Denscombe, 2010, p. 303).

6.2.2 Ethical and social consequences

This thesis' findings constitute a big social implication. They showed the potential IoT has to change the educational system and transform students' and teachers' roles and therefore the whole school system. Education is a vital social institution and a change in the educational system means a social change. Even though IoT can create social benefits, it can also create social issues. In the case of the personalization of the teaching material in accordance to students' interests, it can create ignorance to students as in this case they will only be exposed to what they already know. In any case, it is important for the students to work on the suggested material, since they won't be able to acquire new knowledge if they just receive learning material designed for them without processing it (Ashman et al., 2014).

About ethical consequences: since this thesis' findings are not based on a big sample's perspective, but are rather a perspective of a delimited group of teachers, they cannot be generalized but the sample can be considered a good representative of the teachers' community since it consists of teachers of different areas, level of expertise, ages, sex, topics and years of experience. However these findings can only be considered indicative of the potential IoT can give and is a hint of a situation that might be considered.

Since the personalized material creation according to student's level means that the student might have help only for i.e. a project as a whole rather its separate parts, this can mean that it cannot be quite sure whether a technological tool can predict good learning outcome. This fact can create ethical questions regarding whether such an important context as education can be trusted to a questionable technology. However, since in IoT-based learning, students' needs can be captured with sensors, it might be easier to predict more accurately evidence of true learning than in the case of e-learning as it was described by Ashman et al. (2014).

Another ethical issue discussed also earlier is about the legal part of these tools' use. In order for the students' data measuring to be initiated, GDPR regulation must be modified and adapted to the new reality. Heartbeat, oxygen level etc. are already being tracked and this tracking has already been approved legally. Attention and focus tracking can be considered more questionable and their compliance to the regulation might take more time and effort to occur.

6.2.3 Future research

This thesis examined teachers' perspective regarding IoT integration in Swedish school. Future related research can be headmasters' or students viewpoints. Jacob Michelsen claimed that students should also be included in the dialogue about IoT integration since their role in school's development is crucial.

Another recommendation is an attempt for generalization of this study to a broader group of teachers, throughout a big part of Sweden and why not i.e. Nordic region or Europe. Another future suggestion might have to do with a different methodological approach. Better formulated questions to the same set or other data collection methods and strategies can be considered even if the sample is not quite different. Martin Johansson suggested that it would be important if teachers could have more time to elaborate on their thoughts and if they were interviewed in more carefully formulated questions. Also, test cases according to their suggestions can be created.

Finally, more extensive research concerning the part of teachers' concerns regarding ethical issues and privacy might be conducted. It might include a considerable sample of teachers who will be interviewed for this topic.

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Appendix A: List of tables

Teacher's code name	Field
Teacher.i	Swedish/English
Teacher.ii	Swedish/English
Teacher.iii	English/Media and communication
Teacher.iv	Chemistry/Biology
Teacher.v	Mathematics teacher

Table 2 Workshop: Participants' profiles Workshop SSIS

	Age group	Years of experience	Teacher Diploma	Further Technical Education	First teacher	School level	Subject
Stockholm's City teachers							
Teacher.1	26-35	0-5	Y	Y	N	U.S.S.[5]	English, History
Teacher.2	36-45	15	Y	Y	N	U.S.S.	Swedish, Swedish as a second language
Teacher.3	Over 56	6-15	N	Y	N	U.S.S.	Industry
Teacher.4	36-45	6-15	Y	N	N	U.S.S.	English, Swedish
Teacher.5	36-45	Over 15	Y	Maybe	Y	7-9	Mathematics, Sports
Teacher.6	26-35	6-15	Y	N	N	Preschool	All subjects
Teacher.7	36-45	6-15	Y	Y	Y	U.S.S.	Physics
Teacher.8	46-55	0-5	N	N	N	U.S.S.	IT
Teacher.9	46-55	6-15	Y	Y	N	U.S.S.	Photography, Media Production, Journalism
Teacher.10	46-55	Over 15	Y	N	N	U.S.S.	Social science, Religion
Teacher.11	46-55	Over 15	Y	Y	N	U.S.S.	Language
Teacher.12	26-35	0-5	Y	N	N	U.S.S.	Swedish, Social Science

[5] *U.S.S= Upper Secondary School*

Teacher.13	26-35	0-5	Y	N	N	U.S.S.	Mathematics
Teacher.14	36-45	6-15	Y	N	N	U.S.S.	Swedish, Mathematics
Teacher.15	36-45	6-15	Y	N	N	Preschool	All subjects
Teacher.16	46-55	Over 15	Y	N	N	U.S.S.	Bakery, Pastry
Teacher.17	26-35	0-5	Y	N	N	U.S.S.	Biology, Chemistry, Physics
Teacher.18	46-55	0-5	N	N	N	U.S.S,	Swedish, Media &Informatics, Social
Teacher.19	46-55	Over 15	Y	Y	Y	U.S.S.	Social science, History, IT
Teacher.20	36-45	6-15	Y	Y	N	U.S.S.	Webdesign, 3D interface, digital creation
Teacher.21	46-55	6-15	Y	Y	Y	U.S.S.	Mathematics, Physics, Design, Programming
Teacher.22	36-45	6-15	Y	N	N	1-9	Music, English
Teacher.23	36-45	Over 15	Y	N	N	1-3	Sports
Teacher.24	46-55	6-15	Y	N	Y	All stages	Digitalization, ICT
Teacher.25	46-55	6-15	Y	Y	N	3-9	Swedish, social sciences
Teacher.26	36-45	6-15	Y	N	N	All stages	ICT, Music
Test Round							
Teacher.27	26-35	0-5	Y	N	N	U.S.S.	Swedish, English
Teacher.28	26-35	Over 15		Y	N	U.S.S.	Swedish, English

Table 3 Questionnaire: Participants' profiles[6].

Topic	Responses	Number	Percentage (%)
Sex	Women	14	50%
	Men	14	50%
Age	26-35	7	25%
	36-45	10	35.7%
	46-55	10	35.7%
	56 and over	1	3.6%

[6] Teachers 1-17 are teachers from Stockholm city schools, teachers 18-26 are teachers that found the questionnaire online from Facebook or twitter and teachers 27-28 are the two teachers that responded to it during the test round

Years of Experience	0-5 6-15 16 and over	7 13 8	25% 46.4% 28.6%
Teacher Diploma	Yes No	25 3	89.3% 10.7%
Teaching level	Preschool Levels 1-9 Levels 1-3 Levels 3-6 Levels 7-9 Upper Secondary	2 3 1 1 1 20	7.1% 10.7% 3.6% 3.6% 3.6% 71.4%
IoT term familiarity	Yes Maybe No	19 2 7	67.9% 7.1% 25%
ICT tools familiarity	Not at all Moderately Very much Extremely	1 6 8 13	3.6% 21.4% 28.6% 46.4%
	Total	28	100%

Table 4 Questionnaire: Likert Scale questions responses

	Teacher.A	**Teacher.B**	**Teacher.C**	**Teacher.D**
Age group	26-35	26-35	46-55	56 and over
Years of experience	4 officially, 10 unofficially	6	3	15
Subject of teaching	Chemistry, Biology	Swedish, English	Technology & Entrepreneurship	Mathematics

Table 5 Interviews SSIS: Participants' profiles

Likert-Scale questions Mean Scores

1. *Consider your role as a teacher. Answer on what degree you agree with the following four statements. IoT will create:*

Better course planning for teacher.	More creative teaching for teacher.	More interesting teaching for teacher.
3.46	**3.86**	**3.86**

Table 6 Likert scale questions (1) - Mean scores

2. *How possible is that you use IoT technology in the classroom?*

Possibility to use IoT in class.
3.93

Table 7 Likert scale question (2) – Mean score

3. *Consider your students' role in the classroom. Answer on what degree you agree with the following six statements.With IoT:*

Students will feel more motivated	Students focus will improve.	Teaching will become more inspiring for students	Teaching adapted to individual student's level.
3.36	3	3.55	**4.07**

Table 8 Likert scale questions (3) – Mean scores

IoT applications in classroom

4. In your opinion, how important is the integration of the following applications in the classroom?

Attendance registration	Measure attention with eye-tracking	Measure of brain activity to control focus	Measure air quality	Personal feedback
3.59	2.59	2.4	4.22	**4.37**

Table 9 Likert scale questions (4) – Mean scores

Challenges	Opportunities
-Distraction	-Teaching and feedback adapted to individual
-Time	-Organized material/altogether/easy to access
-Students dependent on technology	-Ability to work distantly
-Shortcuts	-Ability to assess learning
-Information overload	-New things

Table 10 themes from thematic analysis - Workshop

Opportunities	Challenges	Future role
Distant & innovative learning	Cost /Infrastructure problems	Technology enhanced
Individual/personalized learning	Technology competency	Supervisor/Moderator
Less administrative burden	Personal integrity/ethical concerns	Coaching
	Students get distracted	Support
		Not major changes
		Less administrative

Table 11 Themes from thematic analysis - Questionnaire

Problems IoT might solve	Concerns	Suggested uses	Future school
Adapted teaching and feedback to individual/Improved methods	Limited teachers' technology competence	Teachers also to be controlled	Flipped classroom, Distant learning
Motivation	Small steps	Focus/Discipline	More technology
Time	Limitation/ not reliable technology	Progress tracking	Higher knowledge demands
Clean classroom, food, oxygen	Personal integrity/control	Distant/Interactive learning	Less tasks for teachers
Easier interaction and communication		Collaboration	New teaching methods
		Warning systems	
		Interaction/Collaboration	

Table 12 Themes from thematic analysis – Interviews SSIS

Challenges	Suggestions	Needs
Much time spent on administrative	Good air/good results in learning	Less stress/more inspiring
Relation problems with colleagues/ administration is forced from above	IoT as a teaching tool	Children to be included in the dialogue
	IoT can ease data gathering/ Predictive analysis on data can predict success	
	Adapted learning experience/ check progress/Improve teachers' performance	

Table 13 Themes from thematic analysis – IoT hub skola researchers

Appendix B: Informed consent form – SSIS Workshop

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.

Appendix C: Questionnaire – Swedish

Lärare och Internet of Things (IoT)

Mitt namn är Skordeli Eirini (eisk5691@student.su.se) och jag studerar ett masterprogram i data och systemvetenskap vid Stockholms Universitet. Nedan har jag skapat ett frågeformulär för min masteruppsats som handlar om Internet of Things (IoT). IoT innebär möjligheter att förstå allt fler processer i skolan med hjälp av data. Denna uppsats är en del av ett större projekt som heter IoT Hubb Skola som handlar om att utveckla arbetet med användandet av IoT i skolan och nyttja möjligheterna med digitalisering.

IoT Hobb Skola projektet är ett projekt som kommer äga rum under 2018-2020 och är ett samarbete mellan RISE, ett antal skolhuvudmän, Microsoft och Stockholm Universitet. Projektet är finansierat av Vinnova (Sveriges innovationsmyndiget), leds av RISE och samordnas av Kungsbacka kommun. Projektets huvudsyfte är att beskriva vad integreringen av IoT kan betyda för skolan. Under projektets utveckling så kommer riktlinjer att skapas som är förutsatta att influera inte bara det svenska utbildningssystemet men även internationellt.

Här är en video som beskriver projektet.

https://youtu.be/rbQR46LInOI

Du kan hittta mer information om projektet på hemsidan: http://iothub.se/

Samtycke formulär

Jag ber er om ert frivilliga deltagande inom ramen för min masteruppsats. Vänligen, läs följande information om projektet. Om du har ytterligare frågor om denna studie, var god kontakta mig (eisk5691@student.su.se).

Information om studien

Syftet med denna studie är att undersöka vilken potential lärare i svenska skolan tycker att IoT-integration har i undervisningen. Detta frågeformulär kommer att spridas via e-post till läraren.

Analysen kommer att baseras på en kvalitativ utvärdering av lärarens svar.

Den tid som krävs för deltagande: Ca **10-15 minuter**

Potentiella risker med denna studie

Det finns inget förväntat obehag för dem som bidrar till denna studie, så risken för deltagare är minimal. All information behandlas konfidentiellt. Du som svarar på enkäten är anonym. Inga persondata kommer att spåras eller lagras.

Frivillig deltagande

Deltagande i denna studie är helt frivillig. Om du väljer att inte delta, kommer det inte att vara några negativa konsekvenser. Tänk på att om du bestämmer dig för att delta, kan du sluta delta när som helst och du kan besluta att inte svara på någon specifik fråga.

Jag har läst samtycke formuläret och vill fortsätta.

Kryssa i denna ruta om du godkänner villkoren☐

Bakgrund

I. Åldersgrupp *

□ 18-25

□ 26-35

□ 36-45

□ 46-55

□ 56 och över

II. Kön *

□ Man

□ Kvinna

□ Annat/vill inte svara

III. År med lärarerfarenhet *

□ 0-5

□ 6-15

□ Över 15

IV. Har du en lärarutbildning? *

□ Ja

□ Nej

□ Annat:

V. Har du läst kurser/vidareutbilding som rör teknikstött lärande? *

□ Ja

□ Nej

□ Kanske

VI. Är du förstelärare? *

□ Ja

□ Nej

□ Annat:

VII. På vilken nivå undervisar du? *

□ Förskola

□ Lågstadium

□ Mellanstadium

□ Högstadium

□ Gymnasiet

□ Annat:

VIII. Vilket/vilka ämne/n undervisar du i? *

Hur bekant är du med dessa termer?

I. Hur bekant är du med "IKT verktyg"? *

Väldigt lite-Väldigt mycket

1□ 2□ 3□ 4□ 5□

II. Är du bekant med termen "IoT"? *

□ Ja

□ Nej

□ Kanske

IoT och utbildning

IoT är en teknisk infrastruktur som består av inbyggda smarta enheter som kallas "things", som är anslutna via Internet och har förmåga att kommunicera med varandra och utbyta information.

IoT har använts inom många områden inklusive utbildning. De flesta av sina befintliga tillämpningar inom utbildning handlar om administrativa uppgifter och de riktar sig huvudsakligen till högskolor. Några exempel på IoT-enheter som används i utbildning är: huvudband för hjärnaktivitetsenheter, smartwatches för deltagande registrering, enheter med sensorer som mäter syrehalten i klassen för att spåra när eleverna bör ha rast, etc.

Här är en video med några exempel på hur IoT använts i skolan.

https://youtu.be/wrGPPT-gxjw

IoT och undervisning

Fundera över din roll som lärare. Svara på vilken nivå du håller med om följande påståenden.

Med IoT: Som lärare skulle jag få bättre möjligheter till kursplanering.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Med IoT: Undervisning skulle bli mer kreativt.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Med IoT: Undervisning skulle bli mer intressant för mig.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Hur stor är chansen att du skulle använda IoT-teknologi i klassrummet?

Chansen är väldigt liten - Chansen är väldigt stor

1□ 2□ 3□ 4□ 5□

IoT och lärande

Fundera över dina studenters roll i klassrummet. Svara på vilken nivå du håller med om följande påståenden.

Med IoT: Studenterna kommer att känna sig mer motiverade.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Med IoT: Studenternas fokus skulle förbättras.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Med IoT: Undervisning skulle bli mer inspirerande för studenterna.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Med IoT: Undervisning kan anpassas på individuell nivå.

Håller inte med alls - Håller med

1□ 2□ 3□ 4□ 5□

Tillämpningar av IoT i klassrummet.

Hur viktig är integrationen av följande IoT-tillämpningar enligt dig?

Övervaka närvaro.

Inte viktigt - Väldigt viktigt

1□ 2□ 3□ 4□ 5□

Observera uppmärksamhet med ögonspårare (s.k. eye-tracking).

Inte viktigt - Väldigt viktigt

1□ 2□ 3□ 4□ 5□

Mätning av hjärnaktivitet för att kontrollera fokus

Inte viktigt - Väldigt viktigt

1□ 2□ 3□ 4□ 5□

Övervaka luftkvalitet i klassrummet.

Inte viktigt - Väldigt viktigt

1□ 2□ 3□ 4□ 5□

Personlig feedback.

Inte viktigt -Väldigt viktigt

1□ 2□ 3□ 4□ 5□

Några öppna frågor

Det här är den sista delen av frågeformuläret. Jag skulle uppskatta om du kunde ägna några minuter åt att svara på några öppna frågor.

I. Vad ser du för utmaningar med implementering av IoT i skolan?

II. Vilka möjligheter ser du med implementering av IoT i skolan?

III. Hur ser du på lärarens roll i framtiden (om 5 år)?

Tack för ditt bidrag!

Appendix D: Questionnaire - English

Teachers and Internet of Things (IoT)

My name is Skordeli Eirini (eisk5691@students.su.se) and I am a Master student in the Computer and Systems Sciences Program in Stockholm University. The current questionnaire is created for the purposes of my thesis project that is about Internet of Things (IoT). IoT gives new opportunities in schools with the help of computers. This thesis is part of a larger project called IoT Hubb School which is about developing work on the use of IoT in school and utilizing the opportunities of digitalization.

IoT hubb skola project is a project that will take place during 2018-2010 and is a collaboration between RISE, a number of school principals, Microsoft and Stockholm University. The project is funded by Vinnova (the Swedish Innovation Authority). The project is led by RISE and Kungsbacka municipality will coordinate it. The main purpose of the project is to describe what the integration of IoT can mean for the school. During the development of the project, guidelines will be created that are expected to influence not only the Swedish education system but also internationally.

Here is a video description of the project.

https://youtu.be/rbQR46LInOI

You can find more info about the project on its website: http://iothub.se/

Consent form

I am asking for your voluntary participation in my master thesis project regarding teachers and Internet of things (IoT) in Swedish Schools. Please read the following information about the project. If you would like to participate, please sign in the appropriate space below. If you have any further questions about this study, please feel free to contact me.

Information about the research

The purpose of this study is to investigate what potential teachers in the Swedish school think IoT integration has in the teaching. This questionnaire will be distributed via e-mail to the teacher. The analysis will be based on a qualitative and quantitative evaluation of the teacher's response.

Time required for participation: About 10-15 minutes

Potential risks with this study.

There is no expected discomfort for those contributing to this study, so the risk for participants is minimal. All information is treated confidentially. You who answer the questionnaire are anonymous. No personal data will be tracked or stored.

Voluntary participation.

Participation in this study is completely voluntary. If you choose not to participate, there will be no negative consequences. Keep in mind that if you decide to participate, you can stop participating at any time and you may decide not to answer a specific question.
I have read the consent form and want to continue.
Check this box if you agree to the terms □

Background

I. Age group

□ 18-25

□ 26-35

□ 36-45

□ 46-55

□ 56 and over

II. Sex

□ Male

□ Female

□ Other

III. Years of experience

□ 0-5

□ 6-15

□ Over 15

IV. Do you have a teacher exam?

Yes

No

Other:

V. Have you studied courses / further education related to technology-supported learning?

□ Yes

□ No

□ Maybe

VI. Are you first teacher?

□ Yes

□ No

□ Maybe

VII. On what level do you teach?

□ Preschool

□ Low stage

□ Medium stage

□ Junior high school

□ High school

Other:

VIII. What subject do you teach?

How familiar are you with these terms?

I. How familiar are you with ICT tools?

Very little - Very much

1□ 2□ 3□ 4□ 5□

II. Are you familiar with the term IoT (Internet of Things)?

□ Yes

□ No

□ Maybe

IoT and education

IoT is a technical infrastructure that consists of built-in smart devices called "things", which are connected via the Internet and have the ability to communicate with each other and exchange information. IoT has been used in many areas including education. Most of their existing applications in education are about administrative tasks and are mainly aimed at colleges. Some examples of IoT devices used in education are: headbands for brain activity units, smartwatches for participant registration, units with sensors that measure oxygen content in the class to track when students should have a break, etc.
Here is a video with some examples of how IoT was used in school: https://youtu.be/wrGPPT-gxjw

IoT and teaching

Think about your role as a teacher. Answer at what level you agree with the following statements.

With IoT: As a teacher, I would have better opportunities for course planning.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

With IoT: Teaching should be more creative.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

With IoT: Teaching would be more interesting to me.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

How likely are you to use IoT technology in the classroom?
The chance is very small - The chance is very big
1 □ 2 □ 3 □ 4 □ 5 □

IoT and learning

Think about the role of your students in the classroom. Answer at what level you agree with the following statements.

With IoT: Students will feel more motivated.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

With IoT: Students' focus would be improved.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

With IoT: Teaching would be more inspiring for the students.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

With IoT: Teaching can be adapted on an individual level.
Disagree at all - Agree
1 □ 2 □ 3 □ 4 □ 5 □

Applications of IoT in the classroom.
How important is the integration of the following IoT applications in your opinion?

Monitor attendance.
Not important - Very important
1 □ 2 □ 3 □ 4 □ 5 □

Monitor attention with eye-tracking
Not important - Very important
1 □ 2 □ 3 □ 4 □ 5 □

Measuring brain activity to control focus
Not important - Very important
1 □ 2 □ 3 □ 4 □ 5 □

Monitor air quality in the classroom.
Not important - Very important
1 □ 2 □ 3 □ 4 □ 5 □

Personal feedback.
Not important -Very important
1 □ 2 □ 3 □ 4 □ 5 □

Some open questions
This is the last part of the questionnaire. I would appreciate if you could spend a few minutes answering some open questions.

I. What are your challenges with implementing IoT in school?

II. What opportunities do you see with the implementation of IoT in school?

III. How do you see the teacher's role in the future (in 5 years)?

Thank you for your participation!

Appendix E: Consent form (SSIS Interviews)

Consent form

I am asking for your voluntary participation on an interview for the purposes of my master's thesis project. This interview is a semi-structured interview and your participation involves answering to some questions and participating to any discussion around topics that might arise.

Please read the following information about the project:

Information about the research

The purpose of this research study is to examine what potential teachers of Swedish schools find on IoT integration in the teaching process.

The analysis will be based on a qualitative evaluation of the teachers' responses.

Time required for participation: 30-40 minutes

Confidentiality:

The interview will be audio-recorded. The audio recordings will be stored to Eirini's personal computer right after the interview takes place and will be transcribed and deleted afterwards. Only Eirini Skordeli will have access to the recorded audio. All information will be treated confidentially and your participation will be kept anonymous. No personal information will be stored or released. In case some extracts from the interview need to be reported in the study, your personal information will be altered and any details that can reveal your identity will be disguised.

Voluntary Participation

Participation in this study is completely voluntary. Please be aware that if you decide to participate, you may stop participating at any time and you may decide not to answer any specific question.

You can contact me at my email: skordeli.eirini@gmail.com in case you have any questions.

Signature of participant Date

_____ _____

Signature of researcher Date

_____ _____