IoT hubb skola

2019

IoT in education

State-of-the-art regarding teaching and learning

FUNGI – SUBTERRANEAN HUB

“You find twice the amount of life-giving nitrogen and phosphorous in plants that cooperate with fungal partners than in plants that tap the soil with their roots alone... To enter into a partnership with one of the many thousands of kinds of fungi, a tree must be very open. The fungus not only penetrates and envelops the tree’s roots, but also allows its web to roam through the surrounding forest floor. In doing so, it extends the reach of the tree's own roots as the web grows out towards the other trees. Here, it connects with other trees’ fungal partners and roots. And so a network is created, and now it's easy for the trees to exchange vital nutrients and even information – such as an impending insect attack. This connection makes fungi something like the forest Internet...”

Quote from Peter Wohlleben's book *The Hidden Life of Trees* (2016, 50-51)

The picture on the front represents the part of a fungus that can be seen above ground. The actual fungus, which has a life that spans several decades, consists of a network of up to one hundred square metres of underground threads. This network is part of a wider context since fungal threads interconnect with tree roots, which in turn interconnect with various other kinds of fungus that are interconnected with other trees and plants. The network is so tightly woven that a single tablespoon of soil can hold ten kilometres of fungal threads.

IoT hubb skola

STATE-OF-THE-ART REGARDING TEACHING AND LEARNING

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Work report work package 3:1. January 2019.
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This report has been developed as part of the "IoT Hubb Skola" [IoT Hub Education] project, which is part of the strategic innovation programme for the internet of things (IoT Sweden), a joint initiative of Vinnova, Formas and the Swedish Energy Agency.

SUMMARY

This work report has been written within the framework of “IoT Hubb Skola” [IoT Hub Education] development project. The report serves as a milestone within the project and aims to present a first state-of-the-art description of IoT (internet of things) for education, teaching and learning. In the report, we adopt an educational perspective on IoT, and focus on how the introduction of IoT/sensors can support educational activities. The term IoT relates to a number of other concepts and research fields, such as AI, learning analytics, big data and data mining. The report opens with a description of these related fields and a number of delimitations. One example of a delimitation is that we do not focus on cloud services, cloud data, etc. in this report. Instead we look at what the introduction of sensor technology that is new to the school can mean for the education and its activities.

The report is based on a literature review of IoT regarding education, where we tried to find relevant research and, in such case, how IoT/sensors and sensor data are used in educational settings. Additional data was obtained from workshops held in the autumn of 2018. Fifteen people with expert knowledge in at least one of the sub-areas related to the theme IoT/sensors in educationl participated in workshop 1. The overall theme of workshop 1 was “IoT and sensors – opportunities and challenges for the school”. Workshop 2 was organised internally by the Department of Computer and Systems Sciences at Stockholm University within the framework of the department's teaching development work. Needs inventories carried out within the project also provided material for the report.

The results of the literature review indicate that research on IoT/sensors in education is largely lacking. Moreover, we do not find any clear examples of development projects in which IoT/sensors are used to support pedagogical development. A number of articles discuss potential or hypothetical opportunities for the school, but there are no studies evaluating the pedagogical value. Issues and problems regarding ethics, integrity and law are highlighted, along with the need for policy. The workshops that have been conducted provide a similar picture – there are opportunities, but also problems that need to be addressed. The concrete use of IoT/sensors within the context of education, teaching and learning is sparing. Finally, the needs inventories express the need for administrative support. The report concludes with a summary and reflection.

CONTENTS

1. INTRODUCTION

This work report has been written within the framework of the “IoT Hubb Skola” [IoT Hub Education] development project (funded by Vinnova). Kungsbacka Municipality is the coordinating project partner. Other partners in the project are RI.SE Interactive institute, Lidingö Municipality, Västervik Municipality, NTI Upper Secondary Schools of Technology, the Department of Computer and Systems Sciences (DSV) at Stockholm University, Microsoft, Atea, Falköping Municipality, Eskilstuna Municipality, Rytmus and Stadmissionens skolstiftelse.

Schools have a long tradition of technology-supported school development, which in terms of digitalisation dates back to at least the 1960s. Since then, we have seen initiatives such as teaching machines, COMPIS [COMPuter In School] computers, the DIS project, the DOS project, Fyrtornsprojekt [Lighthouse project], “computer driving licences”, the PIM project and 1-to-1 initiatives. Although the results of these initiatives are subject to debate and perspective, it is not possible to ignore the fact that the school has been the arena for a number of initiatives aimed at changing and/or developing (at least some aspect of) the school's activities with support in digital media. With each of these initiatives or implementations, there is a shift in perspective in relation to technology's offerings and the school's opportunities (or needs). What we are now seeing is, among other things, initiatives related to the internet of things (IoT), sensors and learning analytics (LA).

When writing this report, it was with a view of learning that can be most easily described as a union between a sociocultural perspective of learning (where tools are central to human thinking and action) and a sociomaterial perspective of the human-artefact relationship (where these artefacts, or tools, are the bearer of norms and values).

1.1 BRIEF PROJECT DESCRIPTION – WP3:1

In the project description, the purpose of the project is worded as the development of opportunities and potential with IoT in education and in its educational environments. The overall aim of the project is to better utilise the opportunities presented through the IoT in the school by establishing an IoT hub for the school. As part of this work (work package 3:1 (WP3:1)), this work report has been written as a first step in formulating a state-of-the-art description within IoT for education, teaching and learning.

1.2 OUR INTERPRETATIONS AND DELIMITATIONS

As the research project and its focus touches on other related concepts and fields of research, a number of clarifications and delimitations have initially been made here. IoT[1] (internet of things) can be described as networks of physical devices, vehicles, household appliances and other physical objects with embedded electronics, software, sensors and connections that make it possible for these things to connect, collect and exchange data. IoT as a significant component of smart buildings, smart cities, smart public transport, and transport of goods is a topic frequently found in the news and other media. The focus of this project is IoT in educational settings, although the research overview will also address other fields described below – but as a source of inspiration and ideas about IoT in educationl.

There are a number of research areas and concepts that can be said to be closely related to IoT conceptually. One such is *big data*[2], a concept and field

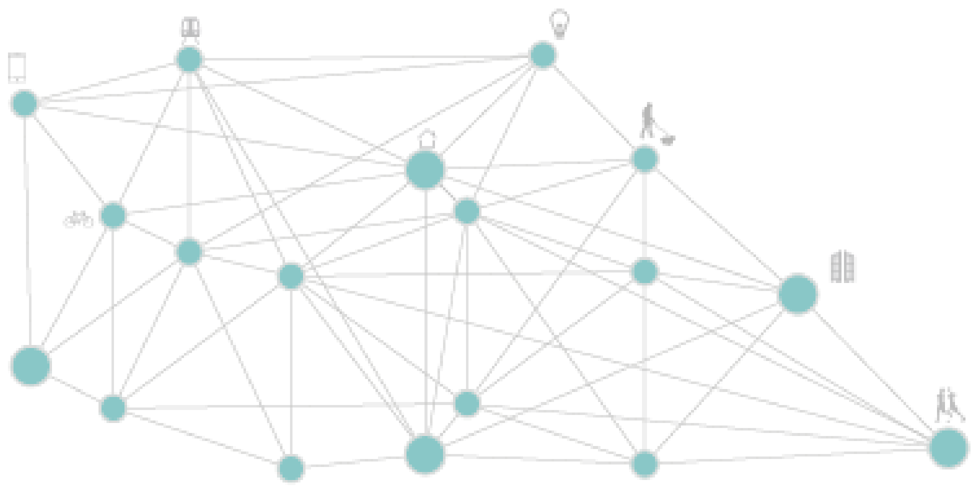

Figure 1. Illustration of the internet of things

that has arisen as a result of large data sets from different data sources being collected and made available for various types of analysis through what is known as *data mining*[3]. In such large data sets, it is possible to search for connections between different data points/variables – connections which

1 https://everipedia.org/wiki/lang_en/iot-internet-of-things-1/

2 https://everipedia.org/wiki/lang_en/Big_data/

3 https://everipedia.org/wiki/lang_en/Data_mining/

might otherwise never be revealed due to the large amount of data. In this manner, complex relationships and dependencies in data can be detected. *Machine learning*[4] and *AI* [5]are another two fields of research that often occur in the context of IoT. The principle is the same, i.e. using big data and self-learning algorithms to try to find connections and patterns in e.g. human behaviour, which can then form the basis for creating so-called "intelligent services". One example of this is a mobile phone app proactively suggesting routes, restaurants, etc. based on phone use and use of GPS data, other apps and sensors. A related field of research is *learning analytics*[6] (LA). A variety of data is continuously stored in the "cloud", on various learning platforms used for educational purposes. This data can be used for analyses of student study results and learning. One objective here is to try to understand what works well and what does not work as well from a learning perspective. From a teaching perspective, such analyses can serve as the basis for changing course design and assignments, and give indications that a teacher may need to perform different types of interventions to support student learning. The field LA is not the specific focus of this project and this report, even though the sensor data collected can also be made available for such systematic analyses. The research overview gives examples of research within the field that is relevant to the topic of this report, and may thereby have bearing on the school.

A *sensor*[7] is an artefact whose purpose is to detect, and often measure, events

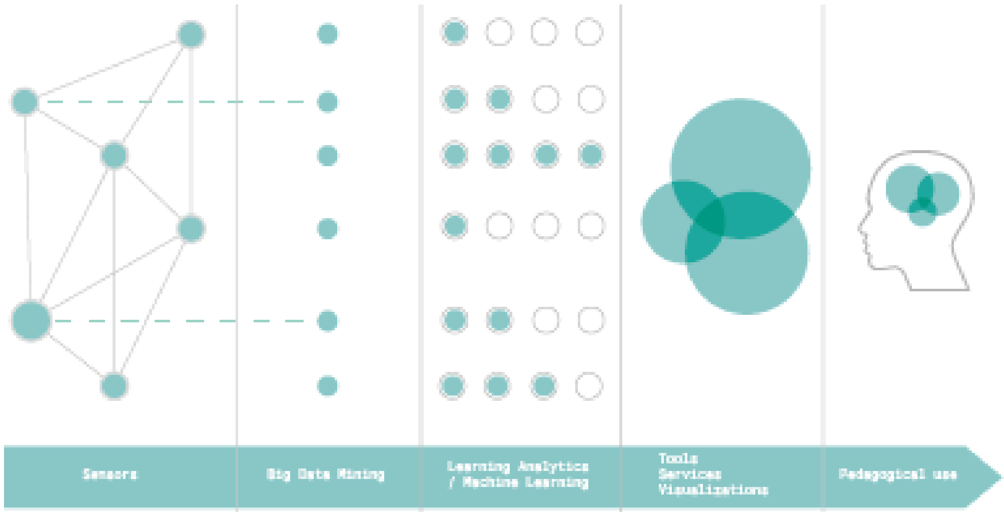

Figure 2. Functions, terms, theories, etc. that frame IoT.

or changes in an environment and to send this information (data) to another device. A sensor can use mechanical, electrical, chemical, optical or other effects to measure physical properties. Typical output from sensors includes temperature, position, weight or identity information. Sensors are found in the digital tools we use, e.g. mobile phones, computers, tablets, cameras, etc. The sensors collect, for example, data on our location and in many cases also about what we are doing. Keystrokes on a keyboard and presses on a touch-sensitive interface (mobile phone/screen) are examples of sensors and sensor data that can be registered, compiled and analysed. In a school context, there are therefore already a number of different types of sensors that record data as well as data on the use of different types of applications, when they are used,

4 https://everipedia.org/wiki/lang_en/Machine_learning/

5 https://everipedia.org/wiki/lang_en/Artificial_intelligence/

6 https://everipedia.org/wiki/lang_en/Learning_analytics/

7 https://everipedia.org/wiki/lang_en/Sensor/

how often, how long, etc. Instead of focusing on the technology and sensors that already exist in educationl, this project focuses on what implications the introduction of new/other sensor technology in the school could have for learning and teaching. In this work, we assume a pedagogical-didactic perspective in the sense that we are interested in conditions for learning in formal/informal learning situations within the context of the school's role.

However, as we explore new sensor technology in the project, we will also use other data that is registered and collected via existing sensors and platforms. Particularly in cases where combinations of data (and thus different data sources) can say more about a phenomenon, about a process related to learning and teaching. The research overview below gives examples of current research on sensors that relates to the topic of this report. This is intended to serve as inspiration for how sensors could be used in education. In order to position sensors in education and in a pedagogical context, we worked according to the thought model illustrated in Figure 3 below.

The school's activities can be understood as an interaction between individuals

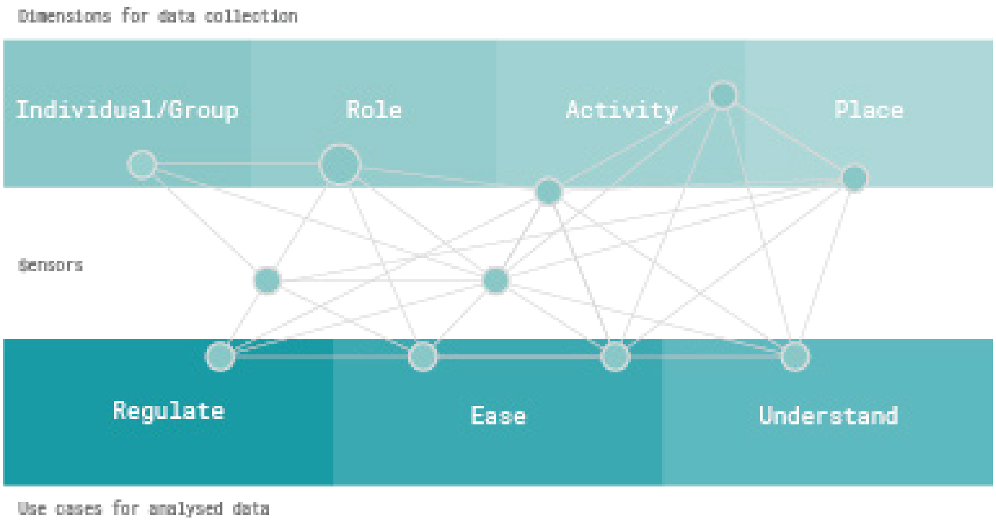

Figure 3: Thought model and point of departure for an educational perspective on the introduction of sensor technology in education.

or groups of individuals, roles (student, teacher, school leader, parent, decision maker, etc.), activities (teacher-led and/or scheduled, but also breaks and other situations without teacher presence or that are not part of formal instruction), and the rooms or locations where these activities take place. Sensors can be used in all of these dimensions or fields to collect not only different types of data but also combinations of data. In an educational context or field, sensors can also be used to, inter alia, control, facilitate and understand a given situation or activities based on different perspectives or needs. The figure therefore illustrates sensors and indicates how they relate to a number of dimensions relevant to education. Sensors and the data registered can, for example, serve as decision and administrative support, or as indications of learning and the need for intervention. Analysis of sensor data can thus be used for different, and in some cases complementary, purposes. The use of sensor data that comes from students' "being" in the school can support teacher understanding of the students' need for support (individual/role/activity) and can also be used for more administrative purposes (role/control/facilitate). Where applicable, data from different sources (sensor data, cloud data, user data) may need to be compiled to collectively say something more than the individual data, in so-called aggregate measurements.

To make the sensor data inspectable, comprehensible and useful (for teachers, students, decision makers, etc.), it must be represented in an appropriate format. The data therefore needs to be processed and representations/visualisations designed in a manner that supports understanding and use. For example, it is possible to visualise the same data in different ways depending on whether it is intended to provide a basis for teachers to be able to perform informed interventions in an activity or to be used by a student to gain a view and reflect on their learning and understanding of a chosen subject or a completed learning activity. We will touch on this thought model more or less explicitly under other headings in this report.

1.3 DATA ON WHICH THE REPORT IS BASED

The report is based on different types of sources. These are external sources (scholarly journal articles and popular science articles, reports, chronicles and other types of media, such as podcasts, videos, etc.), data from e.g. workshops, own experiences, and needs inventories conducted by principals within the context of the project.

As this report is intended to capture state-of-the-art in relation to “IoT for education, teaching and learning”, we started by inventorying scholarly journal articles in this field using Google Scholar (https://scholar.google.se/). An initial search for IoT produced over 700,000 hits, which gives an indication of how the concept touches a number of research fields, which we also briefly mentioned above. For this reason, it was necessary to delimit the search through a combination of search terms. We chose to limit the searches to publications from 2010 and later. In Table 1, we summarise how the search was limited to 144 hits. (Note that K12 also includes “K12”, which is a mathematical formula concept used in certain articles.) By reading the titles and, where relevant, abstracts of these 144 hits and sorting out less relevant articles at the abstract level (technology focus without relevance to education/learning; traditional technology use (learning effects of laptops, etc.); higher education; AR/VR; texts in Russian, Finnish, Chinese), we ended up with 21 titles that were relevant to the topic of this report to a greater or lesser degree. However, most of these 21 articles proved to be of marginal interest.

Search term 1	Search term 2	Search term 3	Search term 4	Search term 5
IoT				701 000
IoT			After 2010	135 000
IoT	School		After 2010	24 100
IoT	School	Education	After 2010	17 800
IoT	School	Learning	After 2010	17 500
IoT	Teaching		After 2010	15 900
IoT	Teaching	Student	After 2010	11 400
IoT	Learning Analytics		After 2010	16 900
IoT	Learning Analytics	Education	After 2010	14 300
IoT	Learning Analytics	Pupil	After 2010	496
IoT	K12		After 2010	290*
IoT	K12	School	After 2010	144

Table 1. Google Scholar search, 4 September 2018. (* K12 can relate to an engineering/mathematical formula (K12). A large number of these hits therefore relate to technology rather than education.)

Journals from the IEEE (Institute of Electrical and Electronics Engineers: https://www.ieee.org/) were frequently among the hits, so a second search focused explicitly on these journals (Table 2). It is worth noting that the hits mainly occur in more technology-oriented journals.

Search term 1	Search term 1	Search term 1	Delimination	Number of hits
IoT	K12		After 2010	1
IoT	Education	-higher education; -campus	After 2010 + "Journals & magazines"	138

Table 2. IEEE Xplore search, 4 September 2018. Most of the 138 hits relate to higher education.

After sorting out titles at the abstract level (technology focus, higher education), 8 of these 138 articles remained. In short, it was determined that there are few scholarly journal articles published with content that has a clear relevance to the topic of this report (IoT and education, teaching and learning). We will return to the actual content of these journal articles later in this report.

In addition to these searches, we also searched for articles, reports and chronicles via search engines like Google and DuckDuckGo. The search terms used were “IoT K12” (Google and DuckDuckGo) and “IoT education” (DuckDuckGo). Here, too, there was a surprising dearth of texts that have a direct link to the topic of this report. Education was often mentioned only as a potential field for the application of IoT/sensors within the framework of e.g. Smart Cities, without any further discussion or specification. The ones which were nonetheless of interest are presented below.

A supplementary search was carried out within the research field “Learning analytics” (LA) and, more specifically, research articles published within an international network “Society for learning analytics research – SOLAR”[8] and “Learning analytics summer institute – LASI”[9]. The aim of this search was to find examples of research carried out in the context of the school, as well as to find examples that could be interesting and serve as a source of inspiration in a school context. A similar search with the same aim was also conducted in the journal “Sensors”[10]. As in the other searches, there were few texts with a direct relevance and a link to the topic of this report. The one deemed to be of interest is presented below.

Knowledge gathering also took place by means of two workshops. For Workshop 1, which was conducted on 15 October 2018 (Tändstickspalatset, Stockholm), we invited researchers and others with expert knowledge in at least one of the sub-areas relevant to the report topic. In total, 15 invitees and 5 individuals from the project participated in this full-day workshop. The overall theme of workshop 1 was “IoT and sensors – opportunities and challenges for the school”. Workshop 2, which was held on 29 October 2018, was organised internally by the Department of Computer and Systems Sciences at Stockholm University within the framework of the department’s teaching development work. Patrik Hernwall and Robert Ramberg once again ran the workshop, which this time focused on how IoT/sensors can support teaching in higher education.

In addition, we incorporated information obtained through needs inventories conducted by principals within the project (WP3:2) as well as our own and previous experiences.

8 https://solaresearch.org

9 http://lasi.solaresearch.org

10 https://www.mdpi.com/journal/sensors

2. RESEARCH AND PRACTICE

As previously indicated, research on IoT and educationl that is relevant to the topic of this report – and to the project in general – is minimal. While the terms education and school may be mentioned in research articles, it is usually in the context that IoT, cloud data, data from learning platforms, sensor data, etc. *may be* relevant to the school. However, research that systematically studies and evaluates applications from an educational perspective seems to be largely lacking.

2.1 RESEARCH IN IOT IN EDUCATION (K12)

A lot of the research reported is based on "big data", i.e. that large data sets in different formats are available to the school on the internet (quantitative data, texts, illustrations, figures, animations, etc.) while a lot of data is collected in the school. There are several examples of research projects where e-books for the school have been developed and evaluated. The advantages of these e-books were said to be that they can be read on different digital platforms and that the e-book suppliers can update them with current examples (e.g. Ogata et al., 2017). The research shows that although IoT can facilitate access to and updating of material that may be included in e.g. e-books, much remains to be done, particularly in regard to the early school years (Moreira et al., 2017). This regards e.g. questions regarding which learning material(s) and in which format. Other research underscores that we, in contemporary society with high broadband speeds, can share and together create knowledge; we can interact with each other and with objects. Here, arguments are put forward for a change towards a more social society where we use the internet to network and remain interconnected. Teaching based on IoT thus gives us the opportunity to cooperate in real time and teach across large geographical distances, while physical location and time of day become less significant (Pei et al., 2013). Others argue that the school of today must face this change and that new theories and frameworks based on these societal and technological changes need to be developed (e.g. Santas, 2015). This form of rhetoric is in no way new and has accompanied technological development for a long time. The fact that technology bridges distances in different dimensions, e.g. time and space, social and cultural, etc., has been used as arguments for innovations like the railway, the telegraph and the internet.

Although major investments are being made within IoT and big data, etc. – particularly in Asia (China, Japan, Singapore, South Korea), where the edtech industry focuses on and contributes to development within the education sector (Liu et al., 2017) – an extensive review of the use of big data in the education sector indicates that there are still major challenges related to security, privacy, ethics, lack of competence, data processing and storage, and interoperability (Bamiah, et al., 2018). These are major challenges that are highly relevant to the school. While IoT exists and is used in large parts of society (e.g. in the transport industry and healthcare), surprisingly few applications are reported in the education sector (Dominguez & Ochoa, 2017), a fact clearly collaborated by the search we performed. Reasons stated for this are the challenges that the school faces (ibid.). Examples of concrete applications in a school context can be found, for example, in the teaching of programming by integrating with physical objects. In one example, students in grades 4–6 programmed interactive doors and university students in interaction design programmed a light source to react to eye blinks and smiles (Rizzo et al., 2018).

Other research focuses on the rapid development of sensors and emphasises the importance of being able to understand and use sensors, including in fields other than engineering and technology, such as more artistic education programmes and professions (Haider et al., 2016). This can be viewed as expression of the fact that if technology becomes ubiquitous, we citizens need to understand it and its possibilities and limitations in a broader context than just “technology”. The use of robots in teaching is also presented as an opportunity for the school. Research on how robots can best be used in teaching is ongoing, and recommendations for how they can be used include in language instruction, robotics instruction, development of social skills, support for students with special needs, and for giving feedback during guided teaching (Cheng et al., 2018; Cai et al., 2018).

IoT presents opportunities for e.g. reaching and following up on students who either dropped out of school or are judged to be on the brink of doing so, as illustrated in an example from India (Rahman et al., 2016). Another example of the use of IoT is in combination with AR (augmented reality). The goal of introducing AR in an educational context is to be able to create and present contextually “aware” educational materials for pupils that are more relevant, engaging and interactive (Sarat Chandra Babu, 2017; Lanka et al., 2017). Research on IoT in education can largely be said to be driven by the rapid advancement in technology that is taking place, and shows in various ways that technology can hypothetically be used in teaching. While technological advancement and the offering to the school are occurring at a rapid pace, questions about how and for what more specific purpose are questions where practical needs must be highlighted and met.

2.2 RESEARCH IN LA AND EDUCATION

Within the field of learning analytics (LA) large data sets (big data) are analysed in order to create understanding for how students learn. The aim is to use such analyses to present suggestions for how the IoT can and should be used to support teaching and learning, and what types of interventions a teacher may need to perform to achieve set goals. Our search for research focused on LA and education was performed in the networks SOLAR[11] and LASI[12], and does not claim to be a comprehensive search and analysis. Selected results from this search are presented below, followed by the results of a search for research on, and the development of, sensor technology in the journal Sensors[13].

Research in LA and education has grown and intensified over the last five years, as illustrated in a comprehensive literature review conducted within LA, big data and the education sector for the period 2008–2017 (Hwang et.al., 2018). A notable result of this literature review (a result also relevant to the topic of this report) is that Sweden, which as a research force is strong in technology and design research, is generally not found among the nations that research and publish most frequently within the field LA. Norway, however, is included in the list. In recent years, Norway (together with Sweden and Denmark) has initiated joint and national initiatives within the field, not least via the "LASI" network. It can be mentioned that Norway has a number of research groups with different specialisations within the field LA and education through the University of Bergen. An observation made in a research project is that it can be difficult to discuss LA in the context of the school since misunderstandings easily arise regarding the aim of LA and how such analyses can strengthen the school and educational work (Slokvik Hansen & Wasson, 2018).

An EU report describes work aimed at assessing the implementations of LA for teaching and training in formal and informal contexts (Ferguson et al., 2016). A further aim of the report is to understand LA's potential to guide and support policy decisions in the direction of adapting LA as a means of improving teaching on a European level. The report shows what was previously described in this text, i.e. that the field LA has ties to a number of other research fields (big data, AI, intelligent services, etc.). The report provides a number of examples of initiatives and applications of LA, along with suggestions for the formulation of policy based on evaluations of completed projects, e.g. Kennisnet[14] in Holland. Questions on ethics in the use of student data and the need for policy to be able to make decisions are also touched on[15]. The report goes on to present a number of examples of LA tools and policies from several countries in Europe and other parts of the world. The report and its contents are too extensive to present in detail in this text, but it is crystal clear that LA is a hot research field and that forces are at work to determine how to best utilise LA in training and education, and to handle the complexity that arises in the processing of big data. This includes matters of law, ethics and privacy (which are also discussed in more detail in *IoT in the school – Privacy, security and law 2019*), and therefore the need for clear policy.

There is big data registered/stored in the education sector. This can be data from student surveys, national tests, tests in different subjects, grades, etc.

11 https://solaresearch.org

12 https://solaresearch.org/events/lasi/

13 https://www.mdpi.com/journal/sensors

14 https://www.kennisnet.nl/about-us/

15 https://help.open.ac.uk/documents/policies/ethical-use-of-student-data

One example of how such data can be used is presented by Aursand & Jonson (2018). A tool (Conexus - Insight) has been developed that makes it possible to retrieve such data about a specific class, group or programme at a specific school. The tool enables comparisons between different schools within and between municipalities in the country, and to make comparisons of study results over time. Naturally, compilations and presentations of such data can serve as support for teachers, head teachers, vice-chancellors and other decision makers in their administrative and educational work. This is just one example, but a great deal of LA research focuses on the development of tools, models and conceptual framework rather than meeting expressed needs and pedagogical aspects (Ferguson et al. 2016). It should be understood here what impact LA has on learning and teaching, and how LA can form the basis for teacher design for learning and support of student learning (Kalisa et al., 2018). An example of this type of direction is to create a conceptual framework that helps teachers understand and use LA to be able to perform interventions and, for example, support student engagement (Koh & Tan, 2017). One such conceptual framework could be to assist in discussions about what LA can offer to the school, and thereby address the problems that have been highlighted in this context (Slokvik Hansen & Wasson, 2018).

In addition to examples of tools for performing meta-analyses that can form the basis for policy decisions, follow-up of study results over time, etc., there are of course also examples of analysis and visualisation of data as support for teachers. Based on an analytical tool (ENA – Epistemic Network Analysis) (Schaffer, 2017), visualisations of student learning can be generated. These visualisations can support the teacher in understanding how students learn, setting grades, and making assessments of grading (Skov Fougt et al. 2018). This type of visualisation can also be used by the students themselves and form the basis for reflections on their own learning.

In multimodal LA (MM-LA), video data is used in combination with other collected data to analyse and understand student learning in different collaboration situations (in laboratories, in technology workshops, etc.) (Spikol et al., 2018). An objective of this research is to use video data in LA in a reliable manner and to be able to better support student collaboration based on a deeper understanding of collaboration and learning. The use of video data can also provide a more holistic picture of learning processes, especially in dynamic learning environments (Spikol et al., 2016; 2018). With the support of video data, it is possible to e.g. generate information about physical movement in a room, a laboratory or a classroom. This includes student movements as well as teacher movements, or lack thereof (Healion et al., 2017). Such information may be valuable in getting an overview of what is happening in a classroom, but can also serve as a tool that both pupils/students and teachers can use for reflection.

Applications of LA are also found in vocational education and advanced education. In a project aimed at training fire and ambulance personnel, data is collected from exercises performed as well as from real-life events, situations and incidents. The objective of the project is to create an overview of the personnel's skills and competencies, and identify which of these require further training. Analyses of collected data can thereby also identify how the training programme should be designed, developed and improved (Slokvik Hansen et al. 2018). Training in military disciplines have long been based on similar approaches, which can be found in e.g. flight simulation and training of professional combat pilots (Aronsson et al., 2018).

In summary, it can be stated that the search for LA and education illustrates that the field is relatively new from a research perspective and mainly focuses on higher education, and that large efforts are being made within the field (e.g. formulation of policy). Furthermore, we see that research focuses on different things, e.g. developing different types of tools that can be used with different and sometimes complementary purposes. Calls are being made that research needs to focus more on the needs of education that include pedagogical aspects (Ferguson et al. 2016). Efforts are being made to enable the creation of a more holistic picture of learning processes by using several different data sources (Spikol et.al., 2018).

2.3 RESEARCH ON SENSOR TECHNOLOGY

Something abundantly clear is that there is a lot of research and development on sensor technology. Much of this research and accounts of the same focus on the technology as such, use of different materials, development and fine-tuning of algorithms, etc. A starting point (and perhaps also a hope) for the search for sensors described here was to find research and development of sensor technology where the area of application and evaluation occurs in a school context that is relevant to the given topic of this report, or where there is reasoning about applications in a school context. Unfortunately, this hope (which was perhaps naive) was not fulfilled. In the literature, there are examples of accounts where sensors are used in buildings (including schools) to measure e.g. temperature and humidity, but the step of utilising and scientifically evaluating such data and functionality from an educational perspective is non-existent. What we chose to highlight here are examples that could also be relevant in a school context – in a future when these sensors and examples do not exclusively constitute research artefacts.

There is interest in using sensor technology to try to identify and detect different types of human activities (Frédéric et al. 2018; Pires et al., 2018). The focus of this research is e.g. the sensors contained in mobile phones (motion sensors, sound sensors, location sensors, magnetic/mechanical sensors). The research exemplifies the identification of everyday human activities, such as washing clothes, cleaning, cooking, brushing teeth, etc. A question arising in such a context relates to what physical activities and movements would be relevant to have identifiable in a school context. Related research also focuses on audio recording for the identification of activities (Pires et al., 2018). Would the identification of activities (sound/voice and movement) be of help in dealing with undesirable behaviours and activities in the school (fights, bullying, etc.), as well as in identifying, encouraging and supporting desirable behaviours and activities? Another question relates to how the identification of activities could be used more directly to support students in their learning and teachers in their teaching.

Research also focuses on dynamic recognition of gestures that have great similarities to recognising other types of human activities (Zhou et al., 2018). Examples of gestures given are relatively simple (e.g. thumbs up, waves, OK signs, how many fingers, etc.) and a similar question asked relative to the previous example can also be posed here once the technology is mature – in what ways could the identification of gestures be used in a school context? Perhaps the identification of different activities together with dynamic gesture recognition could be a valuable resource? Facial recognition sensors are already in use e.g. at Sydney Airport and in Shenzhen, China[16], where the police use it to identify individuals who violate traffic laws and identify smugglers at the border with Hong Kong. They are also able (or are said to be able) to read the minds/mood of individuals and groups of individuals (Wang et al., 2017; Lianzhi et al., 2017). What would a combination of facial recognition, speech recognition, gesture recognition and activity identification mean for the school?

There is also research that focuses on determining position without the use of GPS (Seco et al., 2018). Such technology could be used in the school context to determine movement patterns of both students and teachers in a school, as discussed in the section on LA. Examples include how students and teachers move in a classroom during a class, over the course of several classes, etc. Movement patterns in the classroom and in the school in general combined with the identification of various activities and gestures could potentially serve as a valuable resource for the school.

Achieving and maintaining a healthy life with the support of sensors and smart apps is another example, particularly in sports and sports research. This is the focus of a support for children and parents that helps them keep track of what the individual eats and how much/little the individual moves their body in order to find a healthy balance (Lopéz et al., 2018). This type of support could also be used in a school context – but then perhaps with a focus on the importance of physical activity.

In all examples of possible use of sensor data, we have deliberately not taken any ethical and legal aspects into account. Naturally, there are a number of examples where ethics, privacy and legality are called into question. As emphasised in the EU report on LA research, there is a great need to formulate policies on these issues (Ferguson et al., 2016).

2.4 VOICES FROM THE FIELD

We conducted two workshops. The outcomes and experiences from these have been compiled and are reported below.

Workshop 1
Workshop 1 was conducted on 15 October 2018 and involved a total of 15 researchers and others with expert knowledge in at least one of the sub-areas relevant to the report topic. The overall theme of workshop 1 was “IoT and sensors – opportunities and challenges for educationl”.

Based on a reading of the groups’ work with the scenario “school 2025”, the following overall themes have been crystallised:

16 http://www.digitaljournal.com/tech-and-science/technology/growth-of-facial-recognition-software-in-china/article/518310

Nature and quality of data

It was found that sensors can be used to generate data at the individual and group level (behaviour, movement, pulse, eye movement, biological data). It is also possible to use sensors to measure qualities of the environment (light, sound, air, etc.). By aggregating individual data to a group/school class, it is possible to use sensor data to obtain not only measures of how the students are feeling, but also measures of effectiveness. Two key questions that came to light in this context were: Who owns the data? and How should infrastructural challenges be handled – and what are they?

Privacy and security

A second theme relates to privacy and security, where there are obvious ethical problems (monitoring/privacy), risk of the data being misused or used without regard to students' well-being, and thereby the use of IoT/sensor data being interwoven with issues of power and democracy. At the same time, there was an emphasis on the possibility of personalising the teaching with the support of individual data, which then must be balanced against privacy issues. An additional issue that is important to address is which data we want to collect, use and share – and what mandate the student has to say no.

Monitoring and control, overview and insight

It is possible to monitor individual movements inside and outside of properties using motion sensors with the aim of e.g. reducing vandalism. But, it is also possible to use motion sensors to see where students and teachers are and how they move about in the premises during a lesson, during the school day, etc. and then use such data as the basis for commenting on the relationship between such movements inside and outside of the school building, various interactions, physical activity and performance.

Automation and streamlining

With the help of IoT/sensors, frequently recurring administrative tasks, such as attendance and test correction, can be automated and streamlined to a greater extent than is often the case today. This should, in turn, lead to more time for teaching and instruction planning. When it comes to test correction, it should be possible to individualise this in combination with individual data and individualised test design.

Promote learning processes and the role of the school

Naturally, this theme was the most comprehensive since the overall theme of the workshop was opportunities and challenges for the school. There was also an assumption that the school needs to change in terms of both structure (building, subjects, schedules, classrooms, etc.) and role (what should be taught, in which way). Although these issues are key in relation to pedagogically relevant use of IoT/sensor data, the matter of the school's organisation is a topic that will not be discussed further in this report.

Through gamification and (other forms of) rewards, workshop participants were given an opportunity to make teaching (and school) more fun. The argument is that use of sensor data enables both teacher and students to follow the learning process, and with this have a basis for reflecting over not only their own learning but also their own self. There is also an argument about equivalence, where big data about the unique individual should create better conditions for meeting the individual's needs and thereby promote learning (etc.) based on these unique conditions.

With data that, for example, reflects students' use of various learning resources (time, focus, flows, etc.), the teacher can gain a more solid and authentic foundation for planning and carrying out lessons and learning elements. Here, there is also the possibility of utilising real-time data on air quality, temperature, biodata, etc. to optimise the conditions for students' learning.

Epistemological reflections

A final theme was the nature and conditions of learning. The importance of breaking away from the school structure of the 1800s was emphasised, where alternative learning environments, engagement and individualisation were instead highlighted as important guideposts for a school of 2025. Digital technology and how we choose to use it (as well as the application areas we choose to exclude) will affect our senses, thoughts and actions. But exactly how is open to debate. What role should the school and with that the individuals who spend much of their day there, have in this exploration?

Det var en man från Göteborg [There once was a man from Gothenburg]

som sa att skolan var en sorg [who said that school was a drag]

Aktivitetsbaserad va det han som sa [Activity-based is what he said]

Kan man mäta inlärning, va? [Could be used to measure learning, huh?]

Lösningen är ett sensorutrustat torg! [The solution is a sensor-filled square!]

The above limerick was written by one of the workshop participants as a humorous reflection and summary of the school today, and what it could become.

Workshop 2

Workshop 2, which was held on 29 October 2018, was organised internally by the Department of Computer and Systems Sciences at Stockholm University within the framework of the department's teaching development work.
The theme was how IoT/sensors can support teaching in higher education. Education and teaching at universities differ considerably from that done in schools in many respects, including the fact that students are legal adults. This does not mean that questions of ethics, privacy and law no longer exist, but rather that the students themselves can make decisions on the use of individual data, etc.

Areas discussed include:

- That sensors make it possible to check presence. This can be valuable not only to simplify attendance reporting (via e.g. RFID readers or facial recognition) but also in relation to safety (if there is a fire, for example).

- The possibility of finding connections between e.g. where a student sits in the classroom/lecture hall and their grade/results, or the teacher's workload and well-being. The use of big data alone creates opportunities to study correlations between data points/variables, while making it possible to find new and perhaps unexpected correlations – which may have a bearing on teaching and learning.

- An additional form of sensor that can be used in pedagogical development work is voice recognition. This can be used to gain deeper understanding of who is not only utilising opportunities to speak (e.g. at literature seminars, group presentations, etc.), but also the relation to e.g. grades or teacher interactions. Another opportunity is to use the support provided through "intelligent" voice recognition to make judgements about e.g. a theoretical perspective with its inherent concepts, and whether relationships between concepts are presented and discussed in a correct manner. In other words, if the students can "play the language game" (see Wittgenstein's thoughts about knowledge and development of expertise as learning to master different language games).

- Access to big data via IoT/sensor data also provides the opportunity to explore what is reasonable to measure, what variables are significant to student performance, etc. At the same time, it is important to note that certain qualities, like critical thinking, may be difficult to measure. It is therefore important that strategies for the work forms and development of the university/school are not limited to what is possible to measure with e.g. IoT/sensors (or other measurements with a qualitative orientation).

- That technology like IoT/sensors makes it possible to start with a functional desire (what do we want to have or do?) rather than basing things on established thought models, tools, etc.

- IoT/sensors and, in particular, visualisations of such measurement points (via big data, learning analytics, etc.) can be used as support for students' own learning as well as for peer reviews.

In addition, the possibilities offered by mobile phones for follow-up, feedback (mentometer, etc.) and the like were emphasised, which opens the door to using and combining different types of data sources.

2.5 NEEDS INVENTORIES

At the time this report was written, not all needs inventories had been completed and analysed. Based on workshop materials from approximately 25 groups of teachers and school leaders from two upper secondary schools, one primary school and one preschool, the following needs were formulated:

- Automation of attendance

- Being able to see whether unauthorised individuals are in the school
- Finding available premises, group rooms, classrooms
- Checking whether there is a long queue for the cafeteriaSimpler monitoring and control of the indoor climate, which often has poor air quality, and whether it is hot or cold
- Many different administrative systems which must be logged into and coordinated
- Finding substitutes and checking where substitutes are needed is time consuming

The project is designed as a development project focused on how IoT/sensors can be used in educational activities. It is worth noting that practically all of the needs formulated focus more on administration-oriented tasks, with the exception of checking and safety (unauthorised individuals in the school). In other words, there is a strong expression for support in administration work with themes of safety, checking and saving time. In relation to Figure 3 (thought model), the dimensions “control”, “facilitate” and “room/place” are touched on, with a focus on the teacher and the teacher's administrative tasks. In the research overview carried out and in the workshops conducted, there were several expressions beyond administrative in relation to IoT/sensors and how this could possibly be used in the school.

3. SUMMARY & REFLECTION

3.1 SENSORS IN THE SCHOOL

IoT and sensors relate to a number of different fields. Not unexpectedly, this also became clear in the literature reviews we conducted and reported examples from. The majority of the projects, studies and evaluations described in the literature fall within higher education, but the ideas that are developed and tested can also be relevant to education. We have therefore summarised below selected results from the searches presented above. The choice of which results to present here should be viewed in light of the topic of this report, i.e. an educational perspective on the introduction of sensor technology in the school and the thought model presented earlier (Figure 3).

The use of sensors to identify human activities, voices and gestures (Frédéric et al. 2018; Pires et al., 2018) is an offering for the school. Movement patterns in the classroom and in the school in general, in combination with the identification of different activities and gestures, could prove to be a valuable resource for the school. Such use of IoT/sensors is not only useful in a school context or in pedagogical development work, but also raises a number of ethical, legal and moral questions that the school needs to address. Because regardless of whether it involves implementing new tools (sensors) or using existing and procured tools (like learning management systems), these already collect large amounts of data on the behaviours of individuals. It is in this field that the school needs to develop its – pedagogical and didactic – benefit from IoT and sensors.

Speaking of the lack of pedagogical development work related to IoT/sensors in the school, the creation of e-books may be considered an example of IoT in the school that was found in the literature. E-books are presented as an opportunity for the school (Ogata et al., 2017). Such a suggestion should be seen in light of the fact that edtech companies develop and take responsibility

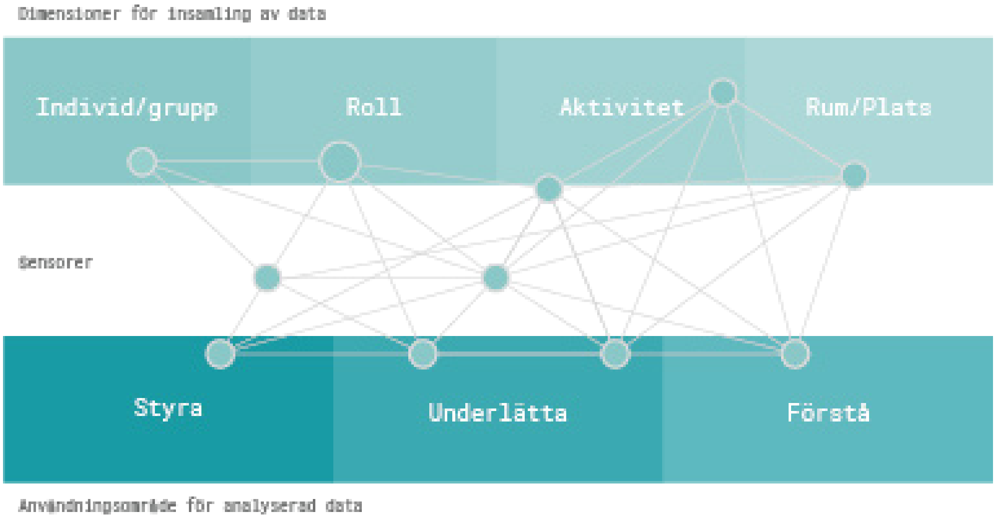

Figure 3: Thought model and point of departure for an educational perspective on the introduction of sensor technology in the school.

for updating the books as well. Like other books, e-books could support students' learning and make things easier for teachers since relevant and multimodal examples and learning materials are made available and updated with some regularity. The books can be read on different digital platforms and in different physical locations. Another example of making learning materials more interactive is e.g. using AR in an educational context (Sarat Chandra Babu, 2017; Lanka et al., 2017). In this context, it is also emphasised that the educational materials for the students should be made more engaging.

There are numerous examples of the use of robots in teaching (Cheng et al., 2018; Cai et al., 2018). A current example is FurHat[17], which was developed at the Royal Institute of Technology in Sweden. Arguments for the use of robots are, inter alia, that they can be used as support for students with special needs, and that students may find it exciting and fun to have a robot as "teacher". As with e-books, the use of robots in teaching would make it easier for teachers and possibly foster engagement on the part of the students, thereby supporting the students' learning. The ability to create different learning activities that revolve around interaction with the robot also opens up new possibilities. But still, this strays a bit from the use of IoT/sensors to promote the development of teaching and learning in the Swedish school environment.

Learning analytics (LA) opens up opportunities for the school to learn about and gain deeper understanding of its activities in a more general endeavour to develop it. Tools that compile and present data that can be used as the basis for decision making in administrative and educational work are being developed, e.g. Aursand & Jonson (2018). LA and the compilation of data can also form the basis for creating visualisations that can reflect students' learning in a chosen subject, as exemplified by Schaffer (2017). Visualisations can also be used by the students themselves as a tool that offers support to reflect over their own understanding and their own learning. Adding video data to other collected data provides opportunities for further insight into collaboration, particularly participation in collaboration (Spikol et al., 2018) and physical movement in the room (Healion et al., 2017).

17 https://www.furhatrobotics.com/furhat/

3.2 USE OF THE IOT AND SENSORS

The following two figures (4.1 and 4.2) are intended to illustrate one of the central challenges we see in relation to implementation and use of IoT/sensors in the school. Figure 4.1 shows the development of IoT/sensors separate from school development. The former is essentially driven by the (technology) industry, where there are already a large number of applications for e.g. smart homes or self-driving vehicles. However, use specifically for the school is minimal, as shown in the summary of the research above. The definition and safeguarding of (or perhaps even the ownership of the idea about) the school's needs and school development is carried out by politicians and civil servants, not necessarily with any dialogue between these two stakeholders. In a fictitious future 2025, the school in this (simplified, certainly) thought model is a more direct consequence of how the school is structured today (which, in turn, is a direct consequence of the school in a near or slightly more distant "then"). The two tracks of technological development and school development run the risk of not only becoming separate entities, but also of missing the target. In this "struggle" between ideas, or ideologies, there is an obvious risk that the school as an idea and an organisation will become fragmented and, with this, lose in its quest for equality.

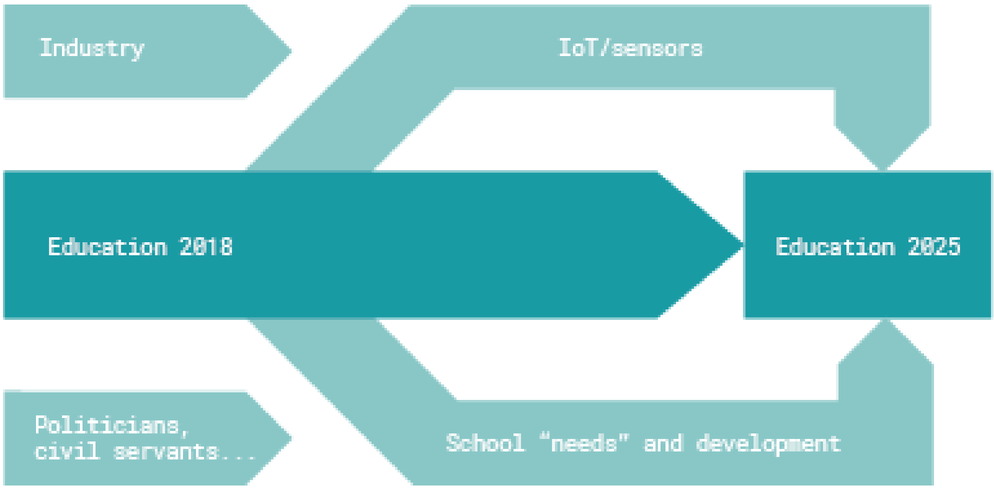

Figure 4.1. Scenario 1.

In the scenario we want to encourage (Figure 4.2), there is instead dialogue between industry and the politicians/civil servants, where the opportunities opened up by IoT/sensors are utilised within the school and the development of IoT/sensors takes place in harmony with the school's needs. In this scenario, the overall objective of school development is solidly rooted in theories of learning, and the quest to make the school relevant as an idea and in practice is high on the agenda. In other words, school development and technological development should stimulate each other.

In this context, we would like to underscore that one of the school's key missions (in addition to democratic education) is to promote the students' utilisation of the tools necessary for the present and the future (regardless of whether these are mental, like mnemonics or critical thinking, or physically concrete, like pen and paper or digital media) in a generally emancipatory endeavour. By releasing the potential that lies in the utilisation of knowledge, competence and ability, the school can be the giant on whose shoulders the student can climb. But in order to achieve this, the school needs to be relevant not only to the stakeholders of Scenario 2 (Figure 4.2), but also to the students themselves, to their guardians and to society as a whole.

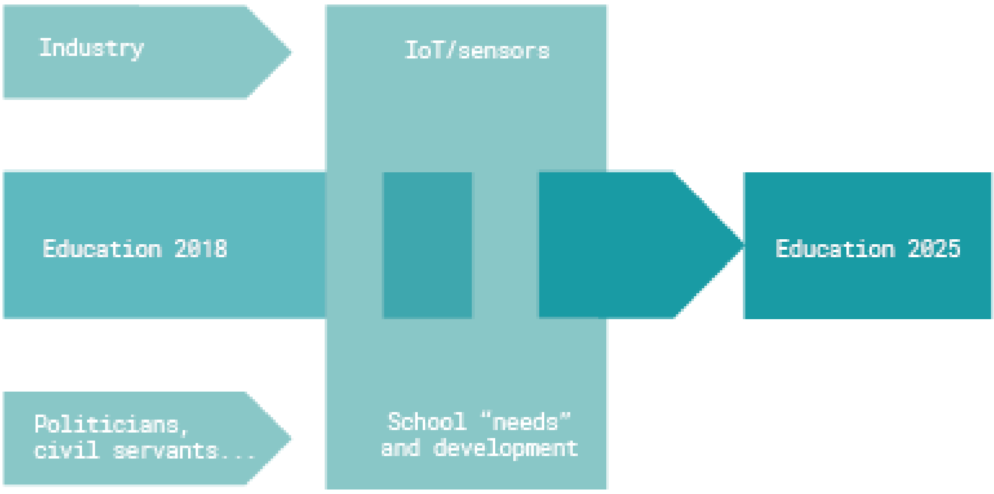

Figure 4.2. Scenario 2.

In relation to the needs inventory carried out in the project and the need for administrative support for teachers that was repeatedly expressed there, it may be important to ask "How does the introduction of administrative support change the school as we know it today?". In relation to Figure 4.1 above, the meeting between new technology and the school as we know it rather becomes a perpetuation of the structures and approaches that already exist, albeit a more efficient version. Naturally, we should not turn a blind eye towards the fact that support in administrative tasks can free up time for teaching or give more time for lesson planning or to spend more time with the students. But, from a development and change perspective, the use of the IoT/sensors holds a lot more potential to support the development of educational activities, both teaching and learning.

3.1 PITFALLS

A key issue for the project, school and society at large is defining the point of departure for change. Is the point of departure preserving and supporting existing structures, or is it to challenge and change them? Challenging the current definition of the school includes questions about what can be considered knowledge, ability, relevant subject areas, etc. and how students can be allowed to demonstrate their knowledge. To us, it is self-evident that it is the school that must be developed, in particular the students' conditions for learning.

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APPENDIX 1:

PODCASTS

There are a few podcasts that illustrate IoT to a greater or lesser extent. The descriptions are from the respective podcast and are thus their own words.

- Den Digitala Draken: https://www.acast.com/dendigitaladraken.

  “Den Digitala Draken” is a subjective but independent depiction of the digital development of services in China. Sound clips from e.g. news reports are used in production. These are used under “fair use” and have not been distorted from their original context and are an important part of the depiction.

- IoT podden: https://www.acast.com/iotpodden.

  “IoT-podden” by Ny Teknik is driven by curiosity and love of the subject. Program hosts Paulina Modlitba Söderlund and Fredrik Karlsson investigate and discuss how the internet of things affects our everyday lives, business transactions, professional life and our society.

- The Internet of things podcast - Stacey on IoT: https://www.acast.com/theinternetofthingspodcast.

  Stacey Higginbotham (formerly Sr. Editor at Fortune) and co-host Kevin Tofel discuss the latest news and analysis of the internet of things. Covers Consumer IoT, Industrial IoT and Enterprise IoT. Guests include Vint Cerf, Om Malik, and people from Amazon.com, AT&T, IBM Watson and more.

- Digitalsamtal: https://www.acast.com/digitalsamtal.

  Podcast that views technological development from a societal perspective.

- Ted Radio Hour: https://www.acast.com/nprtedradiohourpodcast.

  Guy Raz explores the emotions, insights, and discoveries that make us human. The TED Radio Hour is a narrative journey through fascinating ideas, astonishing inventions, fresh approaches to old problems, and new ways to think and create.

- En Podd om Teknik: https://www.acast.com/enpoddomteknik.

  “En podd om teknik” – Sweden's best technology podcast. Each week, we discuss the latest, most interesting and most fun in technology, gadgets, web services and other related categories.

- This Week in Tech: https://www.acast.com/this-week-in-tech-video-hi.

Your first podcast of the week is the last word in tech. Join the top tech pundits in a roundtable discussion of the latest trends in high tech.

- Hur funkar det? https://www.acast.com/hur-funkar-det.

  The "Hur funkar det?" podcast is your guide to the technology all around you. Every other Friday, Karl Emil Nikka and Emma Svensson (Kjell & Co) guide you through a technical solution and answer your questions.

- Ted Talks: https://www.acast.com/tedtalks.

  Want TED Talks on the go? Every weekday, this feed brings you our latest talks in audio format. Hear thought-provoking ideas on every subject imaginable – from Artificial Intelligence to Zoology, and everything in between – given by the world's leading thinkers and doers. This collection of talks, given at TED and TEDx conferences around the globe, is also available in video format.

- Spaningen: https://www.acast.com/spaningen.

  A podcast on digitalisation and learning with Carl Heath and Stefan Pålsson.

- GeekWire: https://www.acast.com/geekwire1.

  GeekWire brings you the week's latest technology news, trends and insights.

- The digital sport insider: https://www.acast.com/the-digital-sport-insider.

  The Digital Sport Insider is an interview series from DigitalSport.co (http://digitalsport.co) founder Daniel McLaren. He sits down to chat 1-2-1 with some of the most interesting and inspiring people who work in digital tech roles within the sports industry. Taking the lid off what it's really like to work in the industry, how they got there and their views on what the future holds.

- Google Cloud Platform Podcast: https://www.acast.com/googlecloudplatform.

  The Google Cloud Platform Podcast, coming to you every week. Discussing everything on Google Cloud Platform from App Engine to Big Query.

- Skolspanarna: https://www.acast.com/skolspanarna.

  "Skolspanarna" is a podcast where two teachers meet each week to discuss school, digital tools and more.

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