Teaching and Learning with Wearable Technologies

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Abstract: This paper presents analysis and findings from a research-driven experimental study that was designed to explore the possibilities of and challenges in the use of wearable computers for supporting learning activities. The overall aim of the study was to explore whether the use of data produced by the pupils in physical education lessons could serve to make abstract numbers and figures more contextualised and concrete, and act as a motivational factor in learning mathematics and social science. The teacher in this study taught all three subjects. The teacher had previously expressed concern regarding the pupils' understanding of mathematical concepts such as graphs, and the pupils had performed poorly on national tests. Our findings suggest that the use of wearables in teaching and learning provides pedagogical opportunities in and across subjects. However, privacy issues emerged both prior to giving the pupils the watches as well as during the study.

Introduction

The term wearable computers covers a range of digital devices that can be worn, often in the form of an accessory such as eyewear or watches or as clothing accessories such as shoes or jackets (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016). These technologies differ from mobile devices in that they can be described as unobtrusive as well as hyper-personal because they also have the ability to measure vital statistics such as health data. According to the Horizon Report (2014), wearable computers will have an important role in education in four to five years. The question is what kinds of uses these technologies will have in education. The current literature in the field is relatively limited (a Google Scholar search with the terms 'wearables' + 'K12' gave 56 results). However, there are some emerging studies that focus on the potential of wearable technologies in K12/primary-secondary education (Bower & Sturman, 2015; Engen, 2016; Lee, Drake, & Williamson, 2015). Studies of head-borne wearables have focused on augmented reality or role-play-related activities, while studies of smartwatches in education have highlighted physical education (PE) and numeracy as possible areas of educational use.

In this paper, our aim is to explore the possibilities and challenges of using wearable computers in support of teaching and learning. We raise the question of how wearable technologies can be used for learning and teaching purposes. Our point of departure was that these watches would produce vital health statistics generated during PE classes, the statistical data could later be processed during mathematics classes, and GPS-generated topographical data could be made use of in Social Science classes.

An important component in Norwegian K12 education is the integration of five basic skills, which include 'digital skills' and 'numeracy' are included (The Ministry of Education and Research, 2006; The Norwegian Directorate for Education and Training, 2012). Digital skills include communication, production and cyber ethics. This latter category has been highlighted as important in the use of smartwatches (The Norwegian Data Protection Authority, 2016).

The paper is organised as follows. We first give a brief overview of studies of wearable technologies in education, and then we explain our research design and case description. We then present our findings and discuss them further in the concluding section.

Wearables in education

There are few empirical studies that examine the use of wearable technologies in education (Bower & Sturman, 2015). Yamauchi and Nakasugi (2003) conducted an early experiment in which they utilised displays attached to the heads of students during history education courses. The students were presented with scenes from both the past and the present in an attempt to enable them to acquire a more visual impression of history by allowing them to view the actual places where important events had taken place. In a more recent study, Wu, Dameff and Tully (2014) tested the use of Google Glass in medical training. The research team concluded that wearable devices have the potential to offer unique possibilities in role-play-based learning contexts. Another study examined the use of Google Glass (Coffman & Klinger, 2015) in educational psychology, and the researchers concluded that this technology fits seamlessly into the lessons, allowing students to take photographs and video recordings of learning activities. Certainly, there are many pedagogical possibilities as well as issues associated with the use of wearable technologies. However, in order for teachers to integrate wearable technologies into their learning designs and to effectively use them in the classroom, they must first understand the potential areas of use of the devices (Bower & Sturman, 2015; Hassoun, 2015). Within special education there has been research examining how wrist-worn devices can support and assist students with intellectual and developmental disabilities in learning (Zheng & Genaro Motti, 2017). Zheng and Genaro Motti (2017) concluded that wearables have promising potential to support students by contributing to their autonomy and reducing the stigma of having a personal assistant who follows and monitors the disabled students' activities. The potential use of wearables has also been studied in relation to e-learning (Labus, Milutinovic, Stepanic, Stevanovic, & Milinovic, 2015), where analysis focused on how the integration of wearable technologies with e-learning systems could support ubiquitous learning and collaboration. A study by Kuzu and Demir (2016) emphasised ethical issues with the use of wearables in education. Besides the pedagogical opportunities, there are major concerns in terms of privacy, copyright and accessibility (Kuzu & Demir, 2016). There have also been studies on using physical activities along with wearable tracking technology as a starting point to teach students about numeracy and statistical data. Lee, Drake and Williamson (2015) designed learning activities for K12 students to look at the potential that wearable tracking technologies have for contextualising and supporting teaching and learning in science and mathematics, with a special emphasis on students' ability to make sense of visualisations of their own produced data. The authors concluded that wearable devices could strengthen the students' learning and understanding of numbers when they produce the data themselves (Lee et al., 2015). These findings imply a rationale for the potential of wearable computers in education. In our study we attempt to understand how wearable computers are used and attempt to gain insight into the challenges that might arise in using this type of technology in the classroom.

Research design

The aim of our research was to examine whether a wearable device could fit into a secondary classroom context and gain insight into what kinds of uses smartwatches might have. Prior to the study a meeting was held at the school, where the researchers and the teacher discussed the possibilities of trying smartwatches in mathematics, social science and PE classes. Subsequently, pupils in ninth grade mathematics, PE and social sciences classes were each equipped with a smartwatch (FitBit Surge) for a two-week period in a Norwegian secondary school (13/14-year-olds). In total, 21 pupils participated in the study (8 girls and 13 boys). The same teacher taught all three subjects in the class.

The idea for this study materialised from an experience with a project that focused on the use of tablets in schools (Engen, Giæver, & Mifsud, 2014a, 2014b, 2014c). One of the challenges that schools face when attempting to use tablets as a replacement for desktop computers and laptops is that tablets were designed as a personal medium. In other words, rather than being designed as a multiuser system, as is the case with most desktop computers, the tablet was conceived as an individual device. Wearable devices are even more personal in that they are borne on the body and measure vital statistics. Our aim was thus to see whether such devices could be used for learning purposes in the classroom, and if so, for what types of educational uses. As such, the research design was exploratory. The study can also be described as partially driven by technology, although the ultimate aim was the use of these technologies for learning.

From an educational perspective, smartwatches are an immature technology. Unlike desktop or laptop computers and handheld devices such as tablets, wearable computers are still rare in the K12 classroom in general. Therefore, in order to test the pedagogical use of wearable computers in education, we were obliged to pursue a more researcher-driven design where we, as researchers, brought the technology to the school.

Data

Data from all lessons during this two-week period were collected by observation (video). Two video cameras were strategically placed at the end of the classroom on tripods. At least two researchers were present during data collection. Researchers also walked around the classroom and observed the pupils. The data obtained from walking around the classroom were not recorded but noted. Pupils were also observed during their PE classes. The pupils wore their watches during breaks but were not filmed due to ethical reasons. The teacher was also interviewed after the two-week period. The interview was transcribed and translated into English by the researchers. In this paper, we draw on an overview of the data that were generated, following an initial viewing of the observational data and an interview with the teacher.

We started by assessing the relatively large selection of smartwatches that were available on the market during the summer of 2015. In reviewing the available selection of wearable technologies, smartwatches aimed at fitness and health improvement were among the most widespread. These devices often include sensors used to measure heart rate, pace and location (longitude, latitude and altitude). They also (often) have predefined settings that are suitable for different workout situations. Additionally, the data produced during workouts and exercises can be shared with friends over the Internet in order to facilitate competition or to encourage users to motivate one another to be more active. Based on a review of the available smartwatches, we made the decision to use the FitBit Surge in our experiment (see Figure 1).

Figure 1. The FitBit Surge

In Summer 2015, the FitBit Surge smartwatch had a built-in GPS for tracking the user's location as well as sensors used to measure the user's pulse rate. Additionally, the FitBit Surge model allowed for the wireless syncing of data to either smartphones or computers via the Bluetooth protocol.

Privacy

In planning the research, we were concerned about the pupils' privacy and other ethical issues. Introducing this technology to schools meant using sensors to track real-time data and physical health information. Therefore, during the planning of this experiment measures were taken to consider the pupils' privacy as well as vulnerability issues related to weight, height and age (being teenagers). Setting up and configuring a smartwatch (such as the FitBit Surge) requires that the user inputs personal data including height, weight, age, gender and other forms of sensitive information. Such hyper-personal data has the potential to stigmatise those pupils who consider themselves too short or too tall or who are either more or less physically mature than their average classmates. Pupils that are already suffering from serious body image problems might be even more focused on their own situations. A pragmatic solution to this problem was to preconfigure all the watches used in the experiment with the average weight and height for 14-year-old girls and boys in Norway, respectively, as retrieved from Statistics Norway (www.ssb.no).

As stated previously, eight girls and thirteen boys participated in our experiment. Accordingly, we configured the 'female' clock with data based on the average height and weight of a fourteen-year-old girl in Norway; we did the same for the 'male' clock using that population's average data. Using such an approach, we felt secure that the students' personal data would not be compromised and that our research would not contribute to any potential on-going discussions of height and weight among the pupils. Furthermore, in order to protect the pupils from sharing location data from their leisure time, the researchers and teacher together came to the conclusion that the pupils would only wear the watches at school (i.e. the pupils would not take the watches home).

In order to get the FitBit to function properly, it was necessary to register and make a user account for each single device on the FitBit website. Registering a device involves providing gender, height, weight, age and other information as well as a working e-mail address. To preconfigure and set up all the devices while protecting the pupils' privacy, we created Gmail accounts with corresponding e-mail aliases for each device. In this way we had complete control of the syncing processes and had access to individual data at the FitBit repository. Each device was tagged physically and linked to an ndividual account. The pupils were asked to memorise the number of the device they used the first day in order to keep the same smartwatch during the project period. The researchers did not know which device belonged to which student.

In preparing the collected exercise data, it became clear that the process of accessing each individual's web portal at fitbit.com was complicated. The data synchronised from the watches following each physical exercise session were posted to a personal repository web page on the FitBit site. Logging in to one's personal web site at fitbit.com would provide detailed information about recent activity as well as statistics regarding activities carried out during the previous months. Utilising the watch's GPS-tracking capabilities, information regarding runs and mobile exercises was presented in detail on a map; such data included information about longitude, latitude and altitude, recorded with an update frequency of 500 milliseconds. Next, the data were exported and downloaded to a computer in an xml format file (Training Centre XML—TCX). Using converter software installed on the computer, the xml file was then converted into a comma separated values file (CVS). Finally, the CVS file was imported into a spreadsheet application (e.g. Microsoft Excel), where the data were presented as numbers in cells and columns.

Exporting the data into a *.tcx file and then converting that file into a format that would be readable by spreadsheet applications was complicated and far too time consuming for the pupils. Moreover, it would have been impossible for one single teacher to complete such a task in the time between the Physical Education class and the mathematics class. Thus, two members of the research team conducted all necessary conversions.

Findings

This study was based on the notion that performing calculations and creating estimates of numbers (data) that the pupils had produced themselves during Physical Education classes would, potentially, serve to make abstract numbers and figures more contextualised and concrete since the pupils would be working with their own data. Another consideration was whether performing calculations that concerned their own physical movements and activities could act as a motivating factor for working with statistical data. Furthermore, since the watch had a built-in GPS that produced topographical data, we were also interested to survey whether the use of the FitBit Surge could be used within Social Science classes.

Based on our observations and the interview with the teacher, we present and discuss the findings related to two key topic areas:

- Potential and actual use in and across subjects
- Privacy issues

During the two-week period, the teacher designed teaching and learning activities that made use of the wearable device and the data it generated in mathematics, PE and social science classes. The pupils' steps, movements, heart rate as well as location data (GPS coordinates such as longitude, latitude and altitude) were tracked. The data were later used in different ways in learning activities in class. In mathematics classes, the data were used to focus on different aspects, such as interpreting tables, creating charts and understanding mathematical concepts including averages, medians and measurement. In social science classes, GPS data were used to learn about map interpretation.

The pupils were first given an introduction to the project and then presented with a rough timetable that indicated when the various activities should occur, conceptualising the cross-curricular idea that guided the activities at school. At the end of the first lesson, the pupils were given the preconfigured smartwatches. After the break, the pupils gathered in the computer lab for an introduction to the spreadsheet. For the remainder of the day, the pupils were engaged in other subjects and activities.

Figure 2. Introducing the FitBit to the pupils

When the pupils first received the watches, they were excited and highly motivated to use them, which is not an unusual novelty effect. The teacher asked the pupils to move around and generate data, which led to a change from the typical classroom activity (sitting) to physical activities such as jumping in class to increase their heart rates, compared with their classmates. To help the pupils become familiar with their watches, the teacher initiated several activities, such as 'walk for 10 minutes during break', 'walk 200 metres' and 'walk a geometrical figure'. After returning to the classroom, the teacher conducted whole class math discussions on measurements, especially on the 200m walk, focusing on how the pupils solved the challenges and discussing different approaches.

Physical Education (PE)
In the PE lessons, the pupils were instructed to initiate the activity tracker on their smartwatches, after which point the teacher proceeded with his lesson as usual, giving them different physical tasks and exercises to complete. The assigned tasks were designed to ensure that there was a mix of moderate and high physical effort.

Between the various activities, the pupils sat on the floor and were given instructions. All the PE lessons were indoors, and thus the activities did not generate data on changes in altitude.

Figure 3. Physical training

During PE class we observed the pupils checking the status on their smartwatches occasionally, but they did not pay much attention to them. Our initial impression was that the potential of the use of the smartwatches in the PE lesson was not fully exploited. The teacher confirmed this in the interview. He mentioned heart rates, defining maximum heart rates and heart rate zones as PE topics that could be explored further. Usually, these topics are covered in tenth grade.

The teacher pointed out that pupils who were typically not very active were motivated by using the smartwatch, suggesting that their motivation stemmed from the fact that the pupils knew that their movements were being registered. He further exemplified this:

> … in most cases, I want to say that the more active the better it is. […] in the PE lessons, that's the essence. […] there were also students who are not necessarily inactive, but perhaps those who move a bit less then, […] when we talked about the steps and the number of kilometres moving for an hour, those were some of them who had moved most. (Teacher)

The introduction of the FitBit in PE classes was a motivation factor for the pupils. The fact that physically passive pupils were motivated to be more active is certainly a positive consequence. However, whether the novelty effect of using the technology would persist over time remains an open empirical question.

Mathematics

During their lessons in the mathematics class, the pupils were instructed to calculate the data that they had produced in their PE class using a spreadsheet. The teacher spent considerable time explaining the user interface and the different statistic functions of the spreadsheet application. In particular, the pupils were introduced to the relationship between cells, rows and columns and were taught how cell addressing works, including how to calculate averages. Other more advanced statistical functions were not in use in the classes we observed. It is important to add that the pupils had limited previous experience in the use of spreadsheets prior to their introductory lesson just a few days earlier.

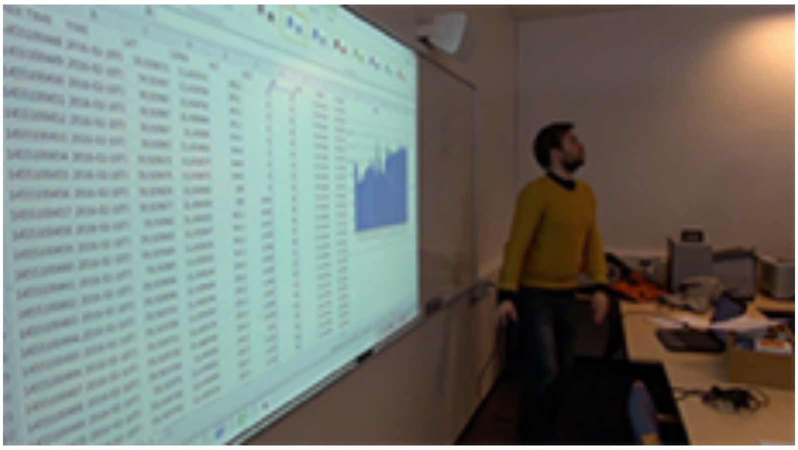

Figure 4. Performing calculations on vital health signs data

Following the brief introduction to spreadsheets, the pupils were presented with the converted data from their activities. The data set was presented as shown in Figure 5. The illustration shows how exercise data taken from the FitBit was presented when it finally reached the conclusion of the export and conversion process. Columns A and B display the time stamp, and Columns C and D indicate location data. Column E shows the altitude above the sea, Column F the distance and Column G displays the user's heart rate.

	A	B	C	D	E	F	G	H	I	J	K
1	UNIX TIME	TIME	LAT	LONG	ALT	DIST	HR	CAD	TEMP	POWER	
2	1461573781	2016-04-25T	59,884923	10,825906	108,6	0	99	0	No Data	No Data	
3	1461573786	2016-04-25T	59,884923	10,825906	108,6	0	99	0	No Data	No Data	
4	1461573791	2016-04-25T	59,884923	10,825906	108,6	0	100	0	No Data	No Data	
5	1461573796	2016-04-25T	59,884923	10,825906	108,6	0,002	102	0	No Data	No Data	
6	1461573801	2016-04-25T	59,884923	10,825906	108,6	0,012	103	0	No Data	No Data	
7	1461573806	2016-04-25T	59,884923	10,825906	108,6	0,024	107	0	No Data	No Data	
8	1461573811	2016-04-25T	59,884923	10,825906	108,6	0,035	111	0	No Data	No Data	
9	1461573816	2016-04-25T	59,884923	10,825906	108,6	0,046	118	0	No Data	No Data	
10	1461573821	2016-04-25T	59,884923	10,825906	108,6	0,057	122	0	No Data	No Data	
11	1461573826	2016-04-25T	59,884923	10,825906	108,6	0,067	126	0	No Data	No Data	
12	1461573831	2016-04-25T	59,884923	10,825906	108,6	0,074	129	0	No Data	No Data	
13	1461573836	2016-04-25T	59,884923	10,825906	108,6	0,08	129	0	No Data	No Data	
14	1461573841	2016-04-25T	59,884923	10,825906	108,6	0,087	136	0	No Data	No Data	
15	1461573846	2016-04-25T	59,884923	10,825906	108,6	0,092	135	0	No Data	No Data	
16	1461573851	2016-04-25T	59,884923	10,825906	108,6	0,092	134	0	No Data	No Data	
17	1461573856	2016-04-25T	59,884923	10,825906	108,6	0,092	133	0	No Data	No Data	
18	1461573861	2016-04-25T	59,884923	10,825906	108,6	0,093	134	0	No Data	No Data	
19	1461573866	2016-04-25T	59,884923	10,825906	108,6	0,098	134	0	No Data	No Data	
20	1461573871	2016-04-25T	59,884923	10,825906	108,6	0,105	132	0	No Data	No Data	
21	1461573876	2016-04-25T	59,884923	10,825906	108,6	0,11	129	0	No Data	No Data	
22	1461573881	2016-04-25T	59,884923	10,825906	108,6	0,119	130	0	No Data	No Data	
23	1461573886	2016-04-25T	59,884923	10,825906	108,6	0,127	132	0	No Data	No Data	
24	1461573891	2016-04-25T	59,884923	10,825906	108,6	0,135	130	0	No Data	No Data	

Figure 5. TCX output

As shown above, the representation of the data could be quite overwhelming for the pupils. The column representing the user's heart rate was chosen for this particular exercise. The pupils were given a task in which they were instructed to calculate their average heart rate from their previous PE class. Then, they were instructed to create a chart using data from the column representing their heart rate and the column representing time.

From our in-situ conversations with the pupils while they worked on their health-sign data sets, it became clear that not all pupils managed to make use of the data that was generated from the device. Some explored the data further, calculating the average speed, discussing what the latitude and longitude data actually meant and searching and comparing the data with the GPS coordinates of the capital, Oslo. However, most pupils needed specific tasks or questions to guide them in exploring the data. Our experience was that they were more motivated when they really understood all the details that could be read and calculated from the data. Overall, with some help, we observed that the pupils had few or no difficulties in understanding the data set generally, but they had different approaches to the tasks, depending on their own competence and abilities.

In the interview, the teacher emphasised that mathematics was the subject that had benefited from the use of the watches:

> Eh, no first and foremost, I'm left with a very good experience […] in relation to the students' use of this […] and engagement around it. Ehm, I think that as they are doing, eh, something that fits with maths at ninth grade, so I feel that the level of engagement was high. (Teacher)

As seen from the quote above, the teacher's experience was that the introduction of the fitness tracker had an impact on the pupils' engagement in the subject in terms of making mathematics concrete—that is, as 'something that ties up with maths'. The teacher further explained that some of the pupils who were usually withdrawn in mathematics class, were passive, and spoke in negative terms about math, were more active when using the devices. These students were particularly active when they were asked to walk in geometrical figures or to measure 200m:

> You get the best learning of maths with them when they [passive pupils] forget that they actually have maths. When they do not think that this is maths. Presenting it as something other than maths, [...], camouflages it in a way. (Teacher)

The use of the wearables appeared to have an added value because the pupils forgot that they were actually doing math, and the watches appeared to give them the necessary incentive to engage with the subject. In the case described above, the mathematics lesson was disguised as something else—walking 200m or in the shape of a geometrical figure—an activity that they could relate to and which was fun. In these activities, numbers and measurements were no longer abstract but rather measurements of the actual steps walked and stairs climbed. As the teacher put it:

> Eh, it becomes so visible and direct with the watches, and they get numbers, they are measurements they can actually see. Now I walk up the stairs, bang, I have walked up the stairs. And because I do that and so, then, I get extra steps, and then they can use it afterwards. Why it was fun to work with it in the computer room I do not know, but I think it's a bit because it's their own data, instead of Per and Kari who count apples and… (Teacher)

As the teacher points out, it appears that the pupils were motivated by analysing their own data, as abstract numbers were contextualised, making numbers real and relevant, and thus relating mathematical data to real life problems. The teacher's reflections on how pupils with different competences and abilities related to the data and the task given demonstrate that such an approach is well suited for differentiated learning. The use of their own data when working with the spreadsheets made it possible for the teacher to help the pupils at their own level. In the case that we described above, the pupils were given the same task. However, they solved it in different ways according to their competence in using spreadsheets and their mathematical abilities. While the pupils' enthusiasm could be related to the novelty of using the watch, we observed that giving the numbers a contextual meaning appeared to help engage the students with the numbers and in working with the numbers.

One of the activities initiated by the teacher was having the pupils walk in the shape of a geometrical figure outside in the schoolyard. The teacher's motivation was concerned to encourage the pupils to actively engage in math. While we were exploring the data from the activity together with one pupil and looking at possibilities for graphical representations, the idea of creating a chart based on the GPS coordinates arose. After trying out different kinds of charts, a dot chart with lines was determined to be the best alternative. This generated a diagram that showed how precisely the pupil was able to walk a geometrical figure. This outcome was then communicated to the teacher, who decided to try it out in class. Such explorative and inquiry-based approaches are recognised as fruitful in teaching and learning mathematics (Goos, 2004).

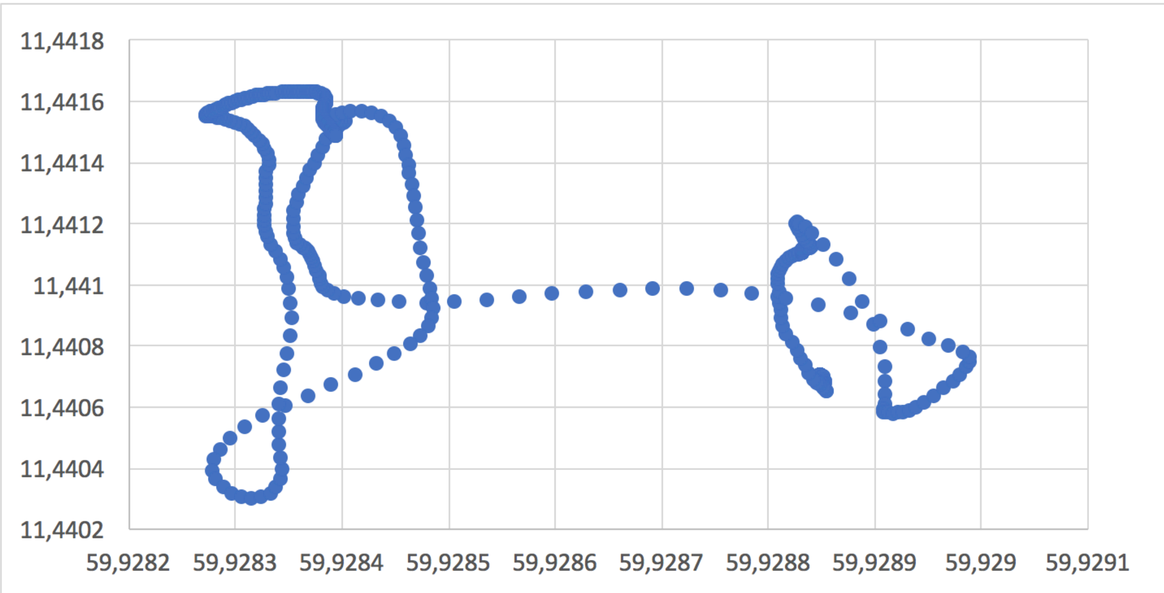

Figure 6. A chart showing movement based on longitude and latitude

Another interesting part of this observation was that the math teacher had not thought through how the data from this activity might be used. While reflecting on the activities, he expressed that this was one of the most valuable learning activities. Furthermore, this idea was also tried out in the social science classes by extending the same activity to create an activity for social science.

Social Science

In social science classes, the use of the watches focussed on the interpretation of maps. The teacher prepared one class by tracking a walk in the local area around the school. In class he presented a map visualising the route he had walked. Then, he asked the pupils to identify and explain the route. All the pupils knew the area close to the school, but they had difficulties identifying where the teacher had actually walked:

> And about the map and the use of the map and so is, so it's very nice to be able to use it for that. Because then we saw that they did not know, that they did not, they did not, it looked like they had no idea about maps. It is—they use maps extremely seldom. So, it took a long time before they realised that this was just right out there. (Teacher)

The teacher here argues for a different use of the watch, where topographical data could be used in a social science class. The teacher expressed surprise that his pupils 'had no idea about maps' and that this was something that the pupils did not work with often. The teacher was also surprised that the pupils did not recognise the area around the school. The graphical representation provided a good basis for discussing map topics such as symbols, topography lines and the map's orientation and scale. The teacher supplemented the map with data on heart rates during the walk, which enriched the talk by highlighting the relations between topography and heart rate, giving practical examples to which the pupils could relate.

The Norwegian Curriculum (2006) specifies that digital skills and numeracy, among others, are basic skills that are to be integrated into every subject at every level in Norwegian schools. The teacher pointed out how the use of the FitBit Surge is obvious in mathematics. He added that the device could be used to support numeracy in all subjects: 'One thing is the watch itself, yes, in mathematics, but you may draw on this in other subjects, numeracy as a, integrated in all subjects.'

Privacy issues

To follow up on the issues we identified regarding privacy when planning and designing the research, we arranged a learning activity in the social science class. At the end of the project period we gathered all the pupils in the classroom to get feedback and examine their reflections about using a smartwatch in learning activities. We were especially interested in discussing privacy and ethical considerations.

At first, we were surprised by the fact that the pupils were not overly concerned with privacy issues, and it appeared that this was more a concern on the part of the researchers and the teacher. The pupils expressed that they had no problems in giving away their GPS location and other personal data. They did not reflect on where their personal data was stored and did not seem to be concerned about this issue at all. The pupils reacted with surprise to the decision of the researchers to pre-configure each watch with average height and weight values as well as to the fact that they were not allowed to use the devices after school. They were not concerned that the researchers could have had access to vital health data and their location. This lack of awareness on the pupils' part might have been due to their limited understanding of the potential risks of using tracking technologies. In the larger picture, it would not be a surprise if their lack of awareness of who has access to health information and location data would apply to nearly all fourteen-year-old children in Norway.

This lack of awareness on the part of the pupils means that the teacher must actively consider privacy when implementing wearable technologies in teaching and learning activities. Thus, a considerable amount of time, effort and advanced technological competency is required of teachers. An added value in integrating smartwatches in this case was that it gave the teacher a practical reason to address these issues with the pupils, thereby raising the pupils' awareness about data protection and privacy—a topic that is also highlighted in the Norwegian Curriculum (2006).

Cloud storage in general—and the storage of data on service providers' computers in particular—is another issue of concern for schools in regard to protecting pupils' privacy. When bringing a wearable device such as a smartwatch into the classroom, the privacy of the information produced and stored on the device is not the only consideration. It is also important to control the link between the device and the data storage location. Failure to address these security concerns could result in serious violations of the pupils' privacy, with all the consequences that entails, particularly given the fact that K12 pupils are minors. Wearable devices, such as the smartwatches used in this project, can easily connect to the Internet via smartphones or computers, allowing pupils to collect, post and share sensitive data about themselves and their peers online (Borthwick, Anderson, Finsness, & Foulger, 2015).

Another issue for consideration is that wearables are not only able to collect and process sensitive information about movement, location, personal health and daily routines; they can also often do this continuously and discretely (Motti & Caine, 2015; Raij, Ghosh, Kumar, & Srivastava, 2011). For the average user, and definitely when it comes to children, it is difficult to fully understand the risks and implications involved in the use of these devices. In this study, the pupils used a wrist-worn device with a built-in GPS sensor. Data about their location and movements could potentially be shared online in real time as live feeds though social media applications from the pupils' smartphones. Based on the privacy issues we faced during this project, it remains unclear whether the wrist-worn wearables used in this study represent a technology that is too immature to be used within the K12 context.

Conclusion

This paper reports on a two-week experimental study on the use of wearables in a secondary school in Norway. The pedagogical rationale behind this case study was based on an assumption that having pupils perform calculations and estimates of figures on data that they had created themselves would increase the relevancy of abstract numbers and figures and make them seem more concrete. Additionally, we sought to gain a deeper understanding of the conditions necessary for the implementation of wearable devices such as smartwatches in K12 education.

Our findings clearly indicate that the introduction of such technologies is motivating for the pupils. This should not be overlooked, as motivation in itself is important in all aspects of learning. A novelty effect was present in our study, but our approach also contributed to making abstract numbers and concepts more contextualised for the pupils. In addition, bringing data generated from a wrist-worn wearable with tracking capabilities into mathematics teaching opens up new creative approaches for engaging pupils in the subject.

In regard to their inclusion and use in different subjects, we argue that wearable technologies are tools that could not only be utilised in concretising that which is abstract, such as numbers and spreadsheets, but also contributes to supporting synergy between subjects. We observed that the data generated in one subject, PE, was used in mathematics and social science classes. In discussing this further with the teacher, he also expressed views on the potential of smartwatch integration in science as well as health and nutrition classes.

Our conclusion is that it is important not to underestimate the value wearables can have in mathematics, where abstract numbers and concepts can be made visual and concrete. We observed that making abstract concepts physical, visual and tangible disguised the ultimate aim of mathematics and engaged the pupils in working with numbers and mathematics. As such, the teacher argued that the subject was made relevant to the pupils.

In planning and preparing this project, we were fully aware that we were introducing a new and immature technology that has various shortcomings with regard to teaching and learning. The transmission of data from the FitBit Surge via an online service to computers was complex and time consuming. This obstacle could have been solved if the pupils had access to smartphones or tablets on which they could have carried out the process themselves. However, such a practice would have demanded considerably more pupil instruction time and may have increased the risk of data loss. Another crucial issue in this experiment was the necessity of protecting the pupils' privacy. Our pragmatic solution to this challenge was to de-personalise the parameters when configuring and preparing the devices. Average weight and height figures for girls and boys were used in combination with fictitious names and e-mail addresses. Allowing the pupils to configure and set up the devices on their own would have increased the risks to their privacy.

Using wearable computers in schools raises fundamental concerns about how to deal with privacy issues. At the same time, the use of smartwatches raises interesting cross-disciplinary possibilities in designing learning activities. However, their use requires that teachers are aware of privacy issues and that they take these aspects into consideration. Questions such as who is in control of the data that are produced and who owns them require serious consideration when bringing such technologies into the classroom (Borthwick et al., 2015).

Technological shortcomings and other practical issues regarding the use of computers in education can be solved. In the case described in this paper, the future technological development of wearable computers might lead to improved and additional features, making wearable computers more appropriate for an educational context. Mobile devices such as smartphones and tablets are largely designed as personal devices. In bringing them into schools in the way that we have implied, a special setup and configuration process is needed, where the intended use based on individual health data must be adjusted—a decision that was not popular in our case but was taken to protect the pupils. The wearable devices that were used in this experimental case take this issue a step further. Despite our precautions to de-personalise the bodily data sent to each watch (with the exception of gender), the pupils' bodies were indeed tracked, and their physical movements were recorded. Bringing such hyper-personal devices into schools and allowing minors to use them requires extensive knowledge and oversight on the part of teachers and/or facilitators; such parties must, in particular, be able to protect their pupils' privacy. As computing has become increasingly cloud-based in recent years, challenges related to privacy have increased for those in the field of education.

While wearables cannot yet be described as ubiquitous in educational contexts, their prevalence is increasing. As the investigation of wearable use in education is at an early stage, educators are in a position to examine both the challenges and potential of such devices.

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