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-Wearable Technologies in the K-12 Classroom — Cross-disciplinary Possibilities and Privacy Pitfalls

Abstract: This qualitative study explored the opportunities and challenges of wearable computers for supporting learning activities. Specifically, we address the following: 1) whether, and if so how, wearable technologies can be used to support learning in and across different subjects and 2) concerns that wearables raise regarding cyber ethics. Our findings suggest that the use of wearables in teaching and learning provides pedagogical opportunities in and across subjects, but this can be time-consuming for teachers and researchers. Furthermore, students were surprisingly unconcerned about privacy issues linked to the use of smartwatches.

Key words: wearables, privacy, cross-curricular learning, K-12

Introduction

The term 'wearable computer' encompasses a range of digital devices that can be worn on the body, often in the form of an accessory such as eyewear, watches, or as clothing items, such as shoes or jackets (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016). These technologies differ from mobile devices in that they are unobtrusive and hyper-personal because they also can measure vital statistics, such as health data. According to the Horizon Report (2014), wearable computers will have an important role in education within the next four to five years.

An important contextual premise in the current study is the Norwegian K-12 national curriculum, which emphasises the integration of five core skills in all subjects: reading, writing, numeracy, oral, and digital skills (The Ministry of Education and Research, 2006), where cyber ethics is included in digital skills. In the current study, our point of interest is using smartwatches to produce vital health and positioning data during PE classes, and later analyse the data during mathematics classes; GPS-generated topographical data could later be incorporated in social studies classes, as well as discussing aspects of cyber ethics related to privacy and data protection.

In the current article, the aim is to explore the opportunities and challenges of using wearable computers in support of teaching and learning in a K-12 environment. Specifically, we explore the following: 1) whether, and if so how, wearable technologies can be used to support learning in and across different subjects and 2) concerns that wearables raise regarding cyber ethics.

Wearables in education

There are few studies that examine the use of wearable technologies in education (Engen, 2016). Several publications (Borthwick, Anderson, Finsness, & Foulger, 2015; Bower & Sturman, 2015; Coffman & Klinger, 2015; Demir & Demir, 2016; Lee, Drake, & Williamson, 2015; Lindberg, Seo, & Laine, 2016; Zheng & Motti, 2017) analyse the potential of wearables for learning. Empirical studies of wearables typically explore two different types of technologies -- eyewear (Coffman & Klinger, 2015; Wu, Dameff, & Tully, 2014) and wrist-worn accessories (Lee et al., 2015).

Lee, Drake and Williamson (2015) discuss the potential that wrist-worn devices have for teaching and learning; they discussed physical education (PE) as their point of departure for helping K-12 students learn to interpret statistical data related to physical activities. Lee et al. (2015) suggest that one way of using wrist-worn devices is to gain an understanding of physical activities -- what statistical data are generated and how the data can be visually represented. Furthermore, Lee et al. (2015) suggest that these devices have the potential to contextualise and support teaching and learning in physical education and across subject areas, especially when it comes to the students' ability to make sense of the visualisations of their own produced data. The potential of making use of tracking technologies as a starting point to teach students about numeracy and statistical data is highlighted by Demir and Demir's (2016) overview of the potential of wearables for supporting learning.

Aiming at gaining insights from knowledgeable educators' perceptions of the potential of wearable technologies in higher education, Bower and Sturman (2015) suggest that understanding the potential of wearables is crucial in capitalising on their educational use; their findings indicate both positive and negative perceptions, highlighting issues such as student engagement, communication possibilities and privacy, and legal and technical issues. Their findings suggest that if teachers and learners are able to perceive and utilise those affordances will wearable technologies find their ways into classrooms (Bower & Sturman, 2015). Several researchers have taken up ethical and privacy issues in the use of wearable tracking devices (Demir & Demir, 2016; Lee et al., 2015; Motti & Caine, 2015). However, although these studies express concern, none of them have inquired into whether students are concerned with issues of cyber ethics.

Research design

The aim of our research is to examine if a wearable device could be integrated into a secondary classroom context. Specifically, we wanted to gain insight into whether, and if so, how smartwatches might support learning while exploring concerns associated with cyber ethics. The current study can be described as both technology driven and researcher driven, in that the technology was introduced to the school by the researchers and withdrawn after the project period ended.

Most smartwatches include sensors that are used to measure heart rate, pace, and location (longitude, latitude and altitude); they also (often) have predefined settings suitable for different workout situations. Additionally, the data produced during workouts and exercises can be shared over the Internet to facilitate competition or encourage users to motivate one another to be more active. Based on a review of the available smartwatches, we decided to use the Fitbit Surge in the current study (see Figure 1).

Figure 1. The Fitbit Surge

In the summer 2015 when we initiated the research, the Fitbit Surge smartwatch had a built-in GPS for tracking the user's location and 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 its Bluetooth protocol.

Ethical Considerations

In planning the research, we were concerned about the pupils' privacy. Introducing this technology to schools meant using sensors to track the students' real-time data and physical health information. Therefore, during the planning of the current study, measures were taken to consider the pupils' privacy, as well as vulnerability issues related to weight, height, and age. Setting up and configuring a smartwatch (such as the Fitbit Surge) requires the user to input personal data, including height, weight, age, gender, and other forms of sensitive information. Such hyper-personal data have the potential to stigmatise those pupils who consider themselves too short or tall or who are more or less physically mature than their other classmates. Pupils who are already suffering from 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 study with the average weight and height for 14-year-old girls and boys in Norway, respectively, as retrieved from Statistics Norway (www.ssb.no).

In total, 21 pupils participated in the study -- specifically, eight girls and 13 boys participated. Accordingly, we configured the 'female' watch with data based on the average height and weight of a 14-year-old girl in Norway; we did the same for the 'male' watch by using that population's average data. Using this approach, we felt secure that 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, to protect the pupils from sharing location data during their leisure time, the researchers and teacher together concluded that the pupils would only wear the watches at school (i.e., the pupils would not take the watches home).

To get the Fitbit to function properly, it was necessary to register and make a user account for each 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 over the syncing processes and had access to individual data from the Fitbit repository. Each device was tagged physically and linked to an individual account. The pupils were asked to remember the number of the device they used the first day to make sure they used the same smartwatch throughout the project period. The researchers did not know which device belonged to which student.

In preparing the collected exercise data for the pupils to use, it became clear that the process of synchronizing, accessing and converting each individual pupil's data from 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 the personal web site at fitbit.com would provide detailed information about recent activity and statistics regarding activities carried out during the previous months. Utilising the watch's GPS-tracking capabilities, information regarding runs and mobile exercises were presented in detail on a map; such data included information about longitude, latitude and altitude, which was recorded with an update frequency of 500 milliseconds. Next, the data were exported and downloaded to a computer in an xml file (Training Centre XML—TCX). Using 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 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 mathematics class. Thus, two members of the research team conducted all the necessary conversions.

Data were collected by observation (video) from all lessons during the two-week research period. Studying classroom activities is complex (Derry et al., 2010); therefore, two video cameras were strategically placed at the end of the classroom on tripods to capture as much of the activities in the classroom as possible. Field notes were taken from walking around the classroom and observing the pupils. Pupils were also observed during their PE classes but were not filmed during breaks because of ethical reasons. The teacher was also interviewed after the two-week period. The interview was transcribed, and the excerpts presented in the current article were then translated into English by the researchers. In the current article, we draw an overview of the data that were generated following an initial viewing of the observational data and an interview with the teacher.

Findings

The current study focused on the use of smartwatches in supporting teaching and learning in and across different subjects in a K-12 environment. The premise here is that performing calculations and creating estimates of numbers (data) that the pupils had produced during physical education classes would serve to make abstract numbers and figures more meaningful. Furthermore, because the watch had a built-in GPS that produced location data, we were also interested in gaining insight into whether the use of the Fitbit Surge could be used within social studies classes. Another aspect revolved around concerns of using smartwatches and cyber ethics (Demir & Demir, 2016; Lee et al., 2015; Motti & Caine, 2015). Although several studies have highlighted concerns with privacy, pupils' awareness of this issue has not been studied. Based on our observations and the interview with the teacher, we present and discuss the findings and relate them to two key topic areas:

- Potential for supporting learning in and across subjects
- Concerns with cyber ethics

Potential for learning in and across subjects

During the two-week period, the teacher designed teaching and learning activities that incorporated the wearable device and the data it generated in mathematics, PE, and social studies classes. The pupils' steps, movements, heart rate and 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 various aspects, such as interpreting tables, creating charts, and understanding mathematical concepts, including average, median, and measurement. In social studies classes, GPS data were used to learn about map interpretation.

The pupils were first introduced to the project and then presented with a rough timetable when the various activities should occur and a conceptualisation of the cross-curricular idea that guided the study's activities. 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 on the spreadsheet. For the remainder of the day, the pupils 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 a usual novelty effect reaction. 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, to increase their heart rates. 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 200 m walk, focusing on how the pupils solved their given challenges.

Physical Education (PE)

In the PE lessons, the pupils were instructed to initiate the activity tracker on their smartwatches, after which the teacher proceeded with his lesson as usual, giving them different physical tasks and exercises to complete. The assigned tasks in PE were designed to ensure there was a mix of moderate and high-intensity activities. 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 the PE class, we observed the pupils checking their status on their smartwatches occasionally, but they did not pay much attention to them. Our initial impression was the potential for using 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 the tenth grade.

The teacher emphasised pupils who were not typically very active were motivated by 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 students. The fact that physically passive pupils were motivated to be more active is certainly a positive side effect. 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 use a spreadsheet to analyse the data they produced in their PE class. 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 used 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 to the pupils after the export and conversion process. Columns A and B display the time stamp, and Columns C and D indicate the location data. Column E shows the altitude above the sea and 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 can be quite overwhelming, especially for students new to this type of data. The column representing the user's heart rate was chosen for the exercise. The pupils were given a task in which they were instructed to calculate their average heart rate from their previous PE class. They were then instructed to create a chart using data from the column representing their heart rate and the column representing time.

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

In the interview, the teacher emphasised mathematics was the subject that had benefited the most 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 noted 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 asked to walk in geometrical figures or to measure 200 m:

> 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 added value because the pupils forgot they were doing math, and the watches seemed 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 200 m or in the shape of a geometrical figure — an activity they could relate to and that was engaging. In these activities, numbers and measurements were no longer abstract; rather, they were the 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 the pupils were motivated by analysing their own data, making abstract numbers contextualised, and the numbers were real and relevant, 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 such an approach is well suited for differentiated learning. In the case we described above, the pupils were given the same task, but worked with the data that they had produced themselves. However, they solved it in different ways according to their abilities in using spreadsheets and their mathematical understanding. Although 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 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 in the schoolyard, as the teacher wanted 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 the 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 option. 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).

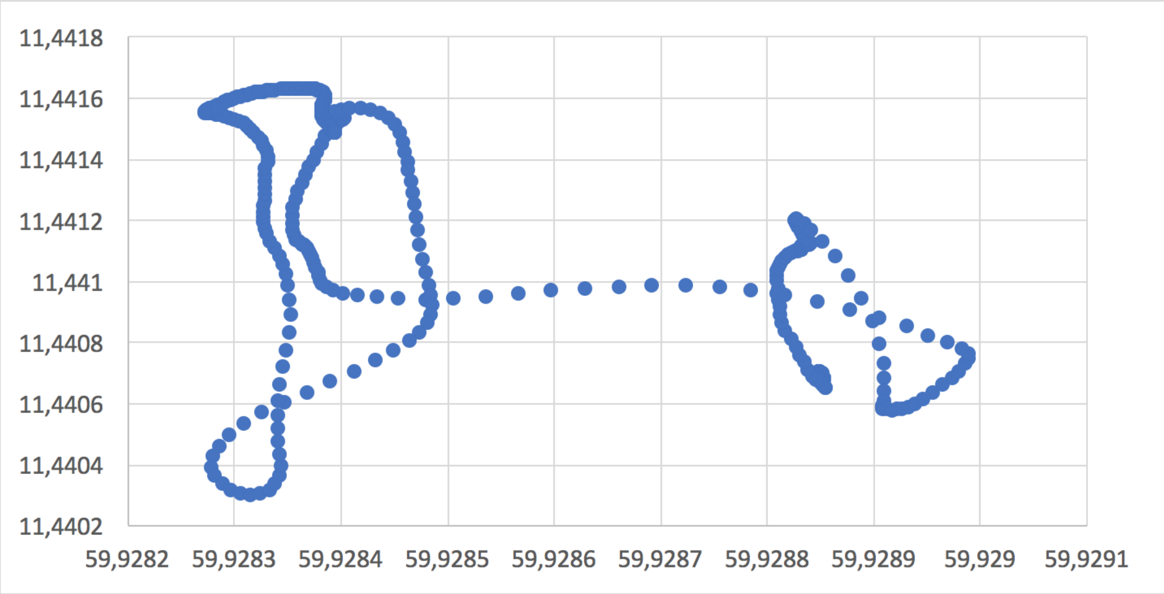

Figure 6. A chart showing movement based on longitude and latitude

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 studies classes by extending the same activity to create one for social studies.

Social Studies

In the social studies classes, the use of the watches focused on the interpretation of maps and privacy issues. 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 had trouble identifying where the teacher had actually walked:

> And about the map and the use of the map [...] it's very nice to be able to use it for that [visualisation]. Because then we saw that they did not know […] 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 outside the school. (Teacher)

Here, the teacher argued for a different use of the watch, where location data could be used in a social studies class. The teacher expressed surprise that his pupils 'had no idea about maps' and that this was something the pupils did not work with often. The teacher was also surprised that the pupils did not recognise the area around the school when it was presented on a map. 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 taken 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: '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'. The teacher reflected that the device potentially could be used to support numeracy in all subjects.

Cyber ethics — 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 studies class. At the end of the project period, we gathered all the pupils in the classroom to obtain feedback and examine their reflections about using a smartwatch in the learning activities. We were especially interested in discussing privacy and ethical considerations.

At first, we were surprised that the pupils were not overly concerned with privacy issues, and it appeared this was more a concern on the part of the researchers and teacher. The pupils expressed that they had no problems giving away their GPS location and other personal data. They did not reflect on where their personal data were 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 and also expressed surprise 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 locations. This lack of awareness might have been because of their limited understanding of the potential risks of using tracking technologies. In the larger picture, it would not be surprising if their lack of awareness of who has access to health information and location data would apply to nearly all 14-year-old children in Norway.

This lack of awareness means 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 who want to use these types of technology. 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 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 regarding 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 data storage location. Failure to address these security concerns could result in serious violations of the pupils' privacy, with all the consequences that this entails, especially given the fact that K-12 pupils are minors. Wearable devices, such as the smartwatches used in the current 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 et al., 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, but 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 the current 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 as live feeds though social media applications from the pupils' smartphones. Currently, based on the privacy issues we faced in this project, it is unclear whether it is prudent to use wrist-worn wearables as learning technologies in the K-12 context. However, the use of wearables can serve to trigger crucial discussions regarding issues of privacy with K-12 pupils.

Conclusion

The current article reported on a two-week study on the use of wearables in a secondary school in Norway. The topics that we addressed were whether, and if so, how wearable technologies can be used to support learning in and across different subjects, and the concerns that wearables raise regarding cyber ethics.

Our findings clearly indicate that the introduction of such technologies can motivate pupils. This should not be overlooked because 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 students. In addition, bringing data generated from a wrist-worn wearable with tracking capabilities into mathematics opens new creative approaches for engaging pupils in the subject.

Regarding their inclusion and use in different subjects, we argue that wearable technologies are tools that could not only be utilised in solidifying the abstract, such as numbers and spreadsheets, but also contribute to supporting synergy between subjects. In discussing this further with the teacher, he also expressed views on the potential of smartwatch integration in science and health and nutrition classes.

It is important not to underestimate the value that wearables can have in mathematics, where abstract numbers and concepts can be made visual and concrete; the relevance of personal data is potentially more meaningful when gathered this way. The aims of mathematics were disguised in 'real' problems, and our observations suggest that the authenticity of the numbers engaged the pupils in working with mathematics.

In planning and preparing this project, we were fully aware that we were introducing a new and immature technology with various shortcomings when it comes 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 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 the current study was the necessity of protecting 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 their privacy risks.

Using wearable computers in schools raises fundamental concerns about how to handle with privacy issues. At the same time, the use of smartwatches raises interesting cross-disciplinary possibilities when designing learning activities. However, their use requires teachers to remain aware of privacy issues and take these aspects into consideration. Questions such as who is in control of the data produced and who owns them require 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 the current article, the future technological development of wearable computers might lead to improved and additional features, making wearable devices more appropriate in an educational context. Mobile devices such as smartphones and tablets are largely designed as personal devices. In bringing them into schools in the way we have implied, a special set-up and configuration process is needed, where how one uses individual health data must be adjusted — an unpopular decision in our case, but one that was taken to protect the pupils. The wearable devices used in the current case take this issue a step further. Despite our precautions to de-personalise the bodily data sent to each watch (except for 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 facilitators; such parties must be able to protect their pupils' privacy. This is all the more difficult for teachers considering that as computing has become increasingly cloud-based in recent years, the challenges related to privacy have increased, especially for those in the field of education.

From an educational perspective, smartwatches still do not appear to be ready for integration in teaching and learning contexts. Unlike desktop or laptop computers and handheld devices such as tablets, wearable computers are still rare in the K-12 classroom in general. Although wearables cannot yet be described as ubiquitous in educational contexts, their prevalence is increasing. Because 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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