ITALIAN JOURNAL OF SOCIOLOGY OF EDUCATION
Editor-in-Chief: Silvio Scanagatta | ISSN 2035-4983

Wearable Technologies as Learning Engines: Evaluations and Perspectives

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Article first published online

February 2021

HOW TO CITE

Matteucci, I. (2021). Wearable Technologies as Learning Engines: Evaluations and Perspectives, Italian Journal of Sociology of Education, 13(1), 161-179.
DOI: 10.14658/pupj-ijse-2021-1-7

Wearable Technologies as Learning Engines: Evaluations and Perspectives

Ivana Matteucci

Abstract: This article presents an experimental study designed to explore the opportunities and challenges associated with wearable technologies in learning activities. The overall aim of the study was to verify whether technology can be a socio-material artefact capable of generating the networks of which it is a part, giving rise to associations between human and non-human elements, producing actions driven by concrete practical activities, and acting as a motivational factor in learning. The socio-material approach has been employed as a key theoretical perspective to describe wearable technologies in learning practices and education research. This perspective, and within it, Actor-Network Theory (ANT), can play a critical role in overcoming the anthropocentric dualism between man and technology, allowing us to focus on the socio-material assemblage of a complex system involving all the agencies operating within the learning process. The methodological approach employed in the present investigation to evaluate the use of wearable technologies in educational activities included participant observation carried out by the researchers in a case study at a high school. In addition, the teachers at the school who participated in the study sat for qualitative interviews during the four-week study period, recounting the students' participation and providing assessments of the effects of the activities. The study highlights the need for new technologies to be integrated with the proper social conditions expressly created within a complex system, where technology is a resource capable of posing problems and generating new knowledge. Within this system, technology performs a mediating function that transforms and modifies the elements that it 'translates', creating new educational practices.

Keywords: wearable technologies, artifact, school, learning practices, Actor-Network Theory

Introduction

The introduction of new technologies in schools has significantly modified the educational experience, including the relationship between teachers and students, and all the material aspects of school teaching. Educational research has long been focused on changes in the use of digital technologies in educational settings. Nevertheless, before delving into this topic, we must reflect on the conceptual categories and cultural and scientific paradigms adopted to interpret the transformations that are currently underway (Ferrante, 2017). Today, a paradigm change is required to address the study of learning processes. Some studies suggest that we must abandon the anthropocentric perspective of traditional humanistic pedagogy to adopt the theoretical perspective of post-humanism, which promotes a new understanding of both educational processes and learning dynamics (Baroni, Ferrante & Sartori, 2014; Ferrante & Sartori, 2016). The anthropocentric perspective is based on the assumption that "the non-human" (objects, technologies, virtual environments..) is clearly separate from "the human", and is considered as an inert and passive object of knowledge, an object without agency, or as a mere tool that teachers and students employ freely to reach predetermined goals.

The decentralization of man and the move towards a post-human paradigm (Badmington, 2003, 2004; Braidotti, 2013; Gane, 2006; Marchesini, 2009), together with the opposition to a dualism that imposed a predominance of the social over the material, culture over nature, rationality over the body, led to the socio-material shift in educational studies. The socio-material approach emphasizes that all learning practices are both inherently material and social. Such a socio-material configuration or assemblage (Suchman, 2007) is a constitutive "entanglement" that recognizes neither independent nor interdependent entities. On the contrary, all entities (whether they be social or technological, human or material) are inseparable (Johri, 2011, p. 210). In the socio-material paradigm, those social and at the same time material elements, aggregate and join forces, becoming the focal point of research and giving rise to new teaching practices and educational scenarios.

In traditional pedagogy, materiality has been understood, above all, in terms of a background (political, social, economic, cultural..), the context in which and from which man ultimately intends, constructs and governs the educational process. In the new perspective, each reality becomes a social and material aggregate, which is at the same time human and technological. The educational experience is made effective by a set of practices that occur materially, invoking technologies, architectural spaces, free or limited passages, nature and objects of all kinds (Fenwick & Edwards, 2010). Consequently, in the experience of learning, cognition is no longer conceived of as an individual fact, but rather as a set of practices, a "distributed phenomenon" among heterogeneous elements (Lichtner, 2016, p. 203). Education is seen as a material entanglement of practices in which heterogeneous actors, human and non-human, enter into a relationship, forming chains and giving life to variably stable hybrid collectives (Latour, 2005). Research is therefore focused on the understanding of the processes through which even very heterogeneous elements are combined.

Among the theories that focus on materiality, proposing a theoretical-methodological reinterpretation of reality that does not separate the social from the material, Actor-Network Theory (ANT) is a particularly interesting approach in the educational field. ANT developed within the STS (Science and Technology Studies) tradition (Law, 2007), also came into widespread use in the human sciences in the mid-1980s thanks to the work of authors such as Bruno Latour, Michel Callon and John Law. Most studies conducted from the ANT perspective aim to trace the way in which human and non-human elements connect with each other, to investigate the processes through which networks of heterogeneous actors are formed (Fenwick & Edwards, 2010; 2012) and to delineate the ways in which the elements that make up a given network interact. Adopting ANT within the post-humanism paradigm and applying it to the field of learning has numerous ramifications. First of all, the object of study in the field of education changes, becoming the analysis of the ways in which human and non-human elements emerge and interact to generate new educational experiences. Furthermore, learning changes from an individual cognitive process or a mere act of socialization, to a product of the interaction between bodies, objects, technologies and the environment (Sørensen, 2009; Fenwick & Edwards, 2010). According to Sørensen (2009, p. 18), the notion of the participant in the learning process applies not only to the learner but also to technology, adopting the ANT principle of "symmetry" (Latour, 1999a; 1996), which recognizes the practical nature of participation and the socio-material construction of knowledge (Latour & Woolgar, 1979).

The methodological equivalent of this form of existence is expressed well by the network concept: «Network is a concept, not a thing out there. It is a tool to help describe something, not what is being described» (Latour, 2005, p. 131). It is through networks and entanglements of "the human" and "non-human" that the role of materiality becomes visible and traceable. ANT relational epistemology, combined with an "anti-dualist" approach, focuses on the relationships between a multitude of elements and the factors that contribute to the construction of networks, rather than on individual entities. Moreover, it denies any foundational distinction prior to the network. Indeed, according to the theorists of this perspective, the network does not connect things that pre-exist autonomously (Sørensen, 2009; Fenwick & Edwards, 2010; 2012) outside of it. On the contrary, the position and identity of each entity, its nature and what it does, depend entirely on the morphology of the relationships in which it is involved (Ferrante & Sartori, 2016, p. 60).

In observing objects, ANT distances itself from both realist and constructivist positions, criticizing the inability of those approaches to account for the complex interactions between human beings and objects (Latour, 1987). Indeed, if, on the one hand, the realists underestimate the power of individuals in the face of the intrinsic influences of technologies, the constructivists, on the other hand, fail to recognize the power exercised by objects over individuals, attributing solely to the human subject the capacity and ability to define and create the reality of which he or she is a part. On the contrary, the ANT approach embraces the perspective called «articulationism» (Mattozzi, 2006, p. 45). "Articulation" is defined as the process of signification of objects that is believed not to require any instance of a subject or mind in order to occur. Instead, this process depends on how the artefact differently reorganizes the network of relationships of which it is part, and which, allying itself with subjects or other objects, it helps to maintain. In this process of signification, "mediation" assumes importance as an inherent element in the situation (Mattozzi, 2006). Here, the term "mediation" does not mean the construction of a bridge to connect two worlds that remain separate and pre-existing (for example the world of objects and that of subjects), but rather the constitution of two instances by a third one, which mediates, i.e., it translates and transforms. In the process of mediation, the technological device involves, brings together or "composes" (Latour, 1999b) a plethora of elements, human and non-human, which together perform specific actions.

Today, the socio-material dimension of techno-scientific processes is clearly evident in daily life. Indeed, everyday life, where the social and material are harnessed in the processes of the construction of reality, is over-populated by technologies. In particular, with the spread of computers and the Internet, technology has become tangible in learning contexts, more so, in fact, than traditional objects and artefacts. It is therefore interesting to trace how new technologies create patterns of relationships that structure educational practices.

The use of technology in the field of education is not a new phenomenon, but the advent of digital technology has dramatically changed the landscape of technologies used in learning practices. From devices such as electronic blackboards, laptops, and mobile phones, to web-based tools such as the Internet, online gaming, and social networking, the infrastructure of learning is becoming increasingly digitalized. This infrastructure is being used to manage content, to facilitate interaction among students and teachers in remote locations, to perform functions such as evaluation, and to conduct experiments. Education is predicted to become even more digitalized in the future, with the adoption of electronic books, augmented reality, game-based learning, and wearable technologies.

According to Johri, there are two major problems with adopting an efficiency orientation with regard to learning technology: technological determinism or sociological determinism. These theories are the result of simplistic, naive notions of technology as a vehicle of efficiency. On the other hand, adopting an empirical interpretive approach that examines technology-in-practice will allow us to understand both the meaning that users attribute to technology and the meaning technology acquires through its implementation (Johri, 2011, p. 208). Based on the specific interpretation of materiality from an ANT perspective, conducting research in the educational field involves considering devices, technologies and objects, not as inert tools, but as the 'protagonists' of educational practices and policies (Landri & Viteritti, 2016) and analyzing educational practices as emergent effects of socio-material assemblages (Fenwick & Edwards, 2010; Fenwick et al., 2011; Fenwick & Landri, 2012). School is therefore a set of heterogeneous elements, a complex system, which cannot be reduced to a neutral place where the teacher, through his or her own intention, educates and transmits contents. Rather, it is a composite of artefacts, spaces, times, rituals and bodies, which intertwine with each other and together give shape to daily practices. School becomes a technologically dense environment, a laboratory, an artificial place that reconfigures, and at the same time, produces knowledge (Viteritti, 2012).

From a socio-material point of view, school, far from being reducible to a rigid, and intrinsically homogeneous immutable structure (Nespor, 2002), is seen, on the contrary, as a network of practices, the contingent effect of continuous negotiations between human and non-human elements (reforms, architectures, spaces, times, bodies, artifacts, speeches, imaginaries) that interact and modify one another (Sørensen, 2009). What we call a lesson, method, school space, school time, student, teacher.., if interpreted from an ANT perspective, become the outcome, albeit a contingent, changeable and unstable outcome, of the particular way in which certain actors and actants (objects whose presence or absence determines a difference in the course of collective action) are aggregated in a specific situation (Mc Gregor, 2004). The educational event appears as the result of a set of socio-material networks in action, acquiring the characteristics of a contingent, unstable and changing process played out by assemblages of human and non-human elements (Barbanti, 2016). The concept of agency, or strength and capacity for change, developed within socio-material approaches, reminds us that things 'perform' (Sørensen, 2009; Fenwick & Edwards, 2012), i.e., they design spaces, create a certain way of doing and being in those spaces, giving shape to what we do, they place us in certain times, they create the conditions for the possibility of future actions.

Wearable technologies in the educational field: studies and applications

The term "wearable computers" covers a range of digital devices that can be worn, often in the form of accessories such as eyewear or watches or clothing such as shoes or jackets. These technologies differ from mobile devices in that they can be described as unobtrusive and hyper-personal. Indeed, they have the ability to measure the weaver's vital signs producing health data. There is currently a limited amount of scientific research on the use of wearable technologies in the educational field. One reason for this is linked to the fact that educators often do not appreciate the potential or «educational affordances» (Bower, 2008; Bower, Sturman & Alvarez, 2016) of these technologies; hence, the need to explore their potential in the field of education is widely recognized (Bower & Sturman, 2015). Several international studies claim that these new forms of technology are destined to have significant repercussions in the educational field (Winkle, 2016, p. XV; Engen et al., 2014). According to Brian Sandall, wearable technologies can become an educational tool capable of enhancing the student's ability to interact with his or her environment in a more natural, innovative and creative way and to access information more easily (Sandall, 2016, p. 80). Josef Ribeiro predicts that educators will increasingly adopt new strategies for the integration of wearables in "project-based and active learning environments" (Ribeiro, 2016).

In a preliminary analysis, de Freitas and Levene (2003) identified the following three main potential applications for these technologies: they provide students with the ability to access teaching materials while on the move, they reduce limitations related to fieldwork since they continue providing access to information and resources in the field, and they provide access to on-the-spot virtual travel using the recording mode. The ability of wearable technologies to foster collaboration has also been recognized, while drawbacks associated with these devices include limitations related to their small interfaces, reduced processing power and slow connectivity (de Freitas & Levene, 2003). Coffman and Klinger have pointed out the advantages of wearable technologies in the educational field, noting that they allow educators to access, interact with, manipulate and create content easily during the teaching process (Coffman & Klinger, 2015). Starting from their preliminary work with *Google Glass*, these researchers have identified the greatest potential of wearable technologies in their ability to generate interest and inspire creativity in students, facilitate collaboration and improve feedback.

Studies have also been carried out on the use of physical activity together with wearable tracking technology as a starting point to teach students about mathematics and statistical data. Lee, Drake and Williamson (2015) designed learning activities for K12 students to assess the potential that wearable tracking technologies have for contextualising and supporting teaching and learning in the natural sciences and mathematics, with a special emphasis on students' ability to make visual representations of their own produced data. The authors concluded that wearable devices could reinforce the students' learning and understanding of abstract concepts and numbers (Lee et al., 2015). With regard to potential problems associated with wearable technologies, their application to learning raises the question of whether or not it is possible to do multiple activities using wearable devices safely and effectively (Nijboer et al., 2013). Concerns related to the recording of videos or personal images followed by their possible use and dissemination, as well as the possible distraction of students in class were also seen as potential pitfalls. The ability of these technologies to instantly transmit information about us and to receive information about other people raises privacy, ethical and social issues. Moreover, as Gill observes, the use of intelligent technologies such as wearable devices could lead to the deterioration of certain skills (such as social intelligence) or limit their development, as people become dependent on technology to support self-knowledge (Gill, 2008).

In the global education system, wearable devices have been used to meet different needs. In particular, in Australia, they have been tested and applied to promote the technological-scientific curriculum (STEM - Science, Technology, Engineering and Mathematics)[1]. Indeed, the education consultancy agency CLWB offered STEM seminars where teachers designed and programmed smart accessories that use wearable devices[2]. In addition, it has been shown that wearable technologies represent an opportunity to increase the interest of girls in STEM disciplines. The female founders of *Jewelbots*, an Australian company that offers friendly programmable bracelets that help girls to learn programming, claim that the goal of their product is to steer young women towards a career in STEM, making technology fun and trendy[3]. In the FUNdamentals summer program of the Department of Design and Merchandising at the University of Colorado, school girls can design 3D printing and computer-aided drawings with wearable devices[4]. Schools have also adopted wearables to meet the needs of flexible classroom

[1] https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/introduction/ (Accessed on 11 August 2020).
[2] https://clwb.org/2015/11/06/australian-technologies-curriculum-stem-workshops/ (Accessed on 11 August 2020).
[3] https://iq.intel.com/jewelbots-inspires-girls-into-stem-with-programmable-wearables/ (Accessed on 11 August 2020).
[4] http://www.avenir.colostate.edu/news/item/?ID=302654 (Accessed on 11 August 2020).

configurations. Israel's MUV Interactive introduced BIRD with a Bluetooth device worn on the finger that projects interactive content from a computer or smartphone onto any surface[5]. Students can make presentations from anywhere in the classroom and manipulate data from their desks while teachers move around among students and groups and facilitate participatory experiences.

Project methods and activities

This study is based on the idea that technology can act as an engine of new educational experiences by stimulating practical activities involving different agencies. Wearable technology provides many educational opportunities in teaching-learning environments, such as student engagement, contextual learning, recording and sharing, evaluation and feedback (Demir & Demir, 2018). In particular, it was observed that the calculations and estimates using data obtained by measuring personal physical parameters (the students engaged in activities and collected data on themselves), served to contextualize abstract numbers and concepts and to make them more concrete (Engen, Giæver & Mifsud, 2017). In addition technology itself and activities driven by technology can also be a motivating factor in the context of learning (Ivi).

The general aim of the study was to explore whether technology can be a socio-material artifact capable of generating networks of which it is a part, giving rise to associations between human and non-human elements. We examined how wearable devices could be adopted in a secondary school classroom context and sought to gain insight into what kinds of agency they might perform. Our aim was to determine whether such devices could stimulate learning practices in the classroom, if their introduction generates new educational experiences, and if so, with what effects.

During a two-week ethnographic observation period, the researchers came into contact with the technology used in the school seeking to observe how the human and non-human elements (artifacts, bodies, spaces, times, etc.) came together to form networks of actors, which in turn gave rise to practices. In order to investigate these networks we used the objects as anchors from which to observe how the human and non-human entities were articulated and connected, modifying one another. Indeed, from an ANT perspective, objects are interpreted as instances of mediation between human and non-human actors associated in chains (Latour, 2005).

Participant observation was conducted using field notes. Applying an ANT analysis to the collected material, the socio-material aggregates were

[5] http://parotec-it.co.uk/index.php/products/bird-by-muv-interactive (Accessed on 11 August 2020).

traced and the networks of actors to which they gave rise and belonged to were described in an attempt to reveal the active role of technology in constituting the observed educational practice. Tracing the socio-material networks that performed the educational practices involved asking ourselves what the objects did, whether or not they reflected the intentions of their designers, what actions they elicited, what role was attributed to them, what elements in particular they connected to, what networks they formed and what effects they produced.

Applying several ANT concepts and tools, a case study at two schools in Central Italy was carried out examining the networks originating from activities with wearable technologies organized at the schools, and seeking to highlight how technological artifacts performed several educational practices. The case study approach was adopted since it is one of the methodologies used by the human sciences for empirical-qualitative research (Van Maanen, 1983; Stake, 1995; Bassey, 2000). Such an approach makes it possible to explore and attribute meaning to practices in a "real life" context (Yin, 1994), and thus allows the researcher to observe and understand how actors behave in everyday situations and environments.

The educational project was developed in March of the 2018/19 school year. It involved a mixed-gender group of 82 students, attending their third or fourth year at a high school in the Marche region. Five teachers supported the activities, including three physical education teachers, and two mathematics teachers.

During the one-month period, the teachers designed teaching and learning activities in physical education class, in which students used wearable devices to generate data. The students' steps, movements, heart rate as well as location data (GPS coordinates such as longitude, latitude and altitude) were tracked. The data were later translated into learning activities in the classroom. In mathematics class, the data allowed teachers to focus on a range of skills, such as interpreting tables, creating charts and understanding mathematical concepts, including averages, medians and measurement.

In physical education class, the students were instructed to initiate the activity tracker on their wearable devices, and the teachers then proceeded to give them different tasks and exercises to complete. The assigned exercises were designed to ensure that there was a mix of moderate and high intensity physical activity. Before beginning the activity, the students were given instructions on how to use the technology as well as some examples. The researchers also walked around the classroom and observed the students. The data that were obtained were not recorded but noted.

Using a computer generated spreadsheet in mathematics class, the students were instructed to make calculations using the data that they had produced in their physical education class. The teachers spent considerable time explaining the user interface and the different statistical functions of the spreadsheet application. In particular, the students were introduced to the relationship between cells, rows and columns and were taught how cell addressing works, including how to calculate averages.

The first study in the research involved the use of smartwatches with heart rate monitors. In this action-research project we were interested in conceptualizing the use of technology in the classroom with the aim of improving student participation. Indeed, an inherent weakness of classroom learning in high school stems from the difficulty associated with trying to get students engaged in the learning process due to program and curricular constraints, and the limited time available for interaction. We therefore wanted to examine the use of technology as a means to maximize participatory learning opportunities for students.

In this case study, the particular context in which the teachers were working was characterized by classes composed of a high percentage of students who were demotivated and superficial both in terms of their approach to study and their analysis of phenomena. The students were also reluctant to accept lecture-style or transmissive teaching, openly displaying their impatience and short attention spans by habitually interrupting the teacher's explanation with inappropriate comments and irrelevant questions. Even the physical education classes, though often introduced with activities and exercises and references to concrete phenomena, were difficult to conduct and not very effective due to the lack of interest shown by the students and their limited participation.The lesson was usually perceived as a moment of play disconnected from any learning program or project.

In terms of their application in the field of education, smartwatches are an "immature" technology. Unlike desktop and laptop computers and portable devices such as tablets (Engen, Giæver & Mifsud, 2014), wearable computers are still generally rare in the classroom. One of the challenges schools face when attempting to use wearables or tablets, stems from the fact that, unlike most desktop computers, which are designed as multi-users systems, these devices are designed for personal individual use. Wearable devices are particularly personal because they can be used to monitor the body and measure vital signs. Our aim was therefore to verify if such devices could indeed be used for classroom learning purposes and, if so, for what types of educational applications.

The research design was exploratory and the study can be described, at least in part, as technology-driven although the ultimate goal was related to the use of the technologies under study in teaching and learning. Before the study began, a meeting was held at the school, where the researchers and teachers discussed the possibility of introducing smartwatches in the subjects of physical education and mathematics. Subsequently, each of the student participants was equipped with a smartwatch for a period of four weeks. In total 25 students participated in the first study (11 females and 14 males).

The initial conception of the use of this wearable technology was rooted in a model that has existed for over a century, namely the "delivery of instruction" model. In other words, a topic could be presented through smartwatches, thus making it more appealing. However, this model was set aside in favor of a participatory model, in which technology is translated from a simple tool to a "tool in a socio-cognitive context" or assemblage. The purpose of the socio-material assemblage was to provide all students with the opportunity to participate and to help guide their participation.

This active student engagement was achieved by giving students the opportunity to acquire data digitally and to then share that data with the teacher and subsequently with the class. The change, fundamental in terms of the use of technology, was also significant from a pedagogical standpoint because it involved creating new participatory learning practices that allowed electronic dialogue (Evans & Johri, 2008). This emerging model was modified as the practice continued to change when new tools and functions became available. The teachers also had to alter their approaches and engage in a socio-material bricolage.

For example, a series of questions and problem solving exercises related to training and physical performance were introduced within the lessons, prompting students to use their smartwatches in different ways. The data that were collected were then transferred to a computer where they were processed and examined by the students. Finally, the students sent the teachers their answers to the questions and solutions to the problem solving exercises and calculations. Over time, the teachers made these exercises shorter but more frequent to keep students engaged. They used software features that allowed them to monitor the students, who in turn could send the teachers their answers to the questions as well as the results of the exercises and measurements taken. These products revealed the student's level of understanding of the particular topic being explored, and their responses were immediately visible to the teachers allowing them to respond immediately and appropriately.

A second study examined the use of wearable technologies in two classes from the same school: a mixed class of 27 students (11 females and 16 males) and a class of 30 students (18 females and 12 males). The activity involved the use of the same wearable device, a smartwatch, for data collection. In one class, the students collected data and, after translating them into graphic representations using a computer, they shared the data in class in face-to-face meetings with teachers and other students, and also through the recording of meetings and focus groups at the end of the study period.

All of the objects (graphs, curves, diagrams, tables, images..) were archived and analyzed. This class met face to face for all the design sessions and made a physical assemblage involving significant use of the technology within the same location.

The other class put in place a virtual design practice in which they simultaneously used instant messaging software (WhatsApp) and a computer application for taking notes and drawing with a digital pen called Microsoft OneNote to interact and to compose. The data were processed by the students using a computer program that allowed them to work together on the project. At the same time, on a social platform, they exchanged proposals, impressions and comments while changing, adjusting, and revising the project. This was already an emerging practice that arose to meet the need of students who were unable to physically interact outside of the classroom, and the practice evolved over the course of the study period. The students tried out different ways to develop a learning practice - an assemblage - that would help them overcome the obstacles to working together and complete their project.

The two classes were compared. We performed a comparative analysis of the two classes which set out to design the same objects, but which adopted markedly different processing practices.

Findings

In the first study, participant observation showed that when students first received smartwatches, they were enthusiastic and highly motivated to use them, which is not an unusual novelty effect. The teacher asked the students to move around in the classroom and generate data; hence, they abandoned the typical position assumed in the classroom, namely sitting, and began doing physical activities, such as jumping or running to increase their heart rates. To help students familiarize themselves with their smartwatches, the teacher had them do various activities, such as "walking for 10 minutes", "taking a short run" or "going up and down steps for 5 minutes". The teacher then led discussions involving the whole class on the measurements that the students had performed, focusing on how students dealt with the challenges they encountered and the different approaches they adopted. The introduction of the smartwatches in physical education classes was a motivating factor for students. The fact that passive students were physically motivated to be more active and to participate is certainly a positive consequence. However, whether the novelty effect of the use of technology will persist over time remains an open empirical question.

In the second study, our analysis showed that, to achieve successful results, computational devices and accompanying software must support two aspects of the research design process: representational practices and relational practices. Representative practices include all aspects of creating and transforming representations, such as drawing tables, transcribing verbal descriptions, calculating numerical data, and converting one form of information into another such as converting a formula into an algorithm.

Relational practices refer to the interactional aspects of the project activity, namely the way team members communicate and subsequently work together with one another. These two practices are closely intertwined. Regarding the first class, face-to-face interaction, representations, gestures and physical movements were all part of the practice of the project. In the technology-mediated contexts, particularly in the second class, the students created this context using the synchronous chat tool and a concurrent OneNote session to share hypotheses and work together on a developed protocol. Over the course of the research period, they developed their practices - both the social and material elements - to generate a better final product. Once again, in this study we see a socio-material bricolage in action. The students did research on learning technology using the available tools, ensuring that the social and material elements were aligned and supporting each other.

Participation observation was also used in this case. The researchers noted that the students felt comfortable using the various technologies, which were integrated as actors of the project with the real flesh-and-blood actors, individually or in groups. Here the combined influence of human actors and material artifacts gave shape to the educational practices that took form in the school under study.

In order to ascertain the points of view of the participating teachers we designed the interviews in such a way as to allow the participants to act in dual roles, that of school teacher and that of observer of an artifact. The data obtained from the interviews were then crossed-checked with the observation data to further explore certain elements and discover other new ones.

We therefore tried to anchor the narrative of the interviewed teachers to the artifact that was employed (smartwatch) suggesting that they talk about it, with the aim of mediating and therefore relating by translating the "form" or world of the object and the "expression" or world of the interviewed subject (Mattozzi, 2006). Using this "activation" approach we conducted four topical interviews of about thirty minutes each, which were recorded and subsequently transcribed in full.

The smartwatch was first introduced into classroom through movement, by having the students get up from their desks, and walk up to the small cupboards mounted on the classroom wall in which the individual watch holders were kept. The teacher-device-student aggregate described above, highlights the presence of a particular movement in the classroom space, peformed by the students to take possession of the device and begin using it.

The next action involved putting the device on, bringing it into contact with the student's body and thus allowing it to become part of the user's life. The subsequent movement of the students in the classroom, authorized by the teacher, led to the emergence of novel spaces within the classroom. These brand new spaces were generated by the devices, driven by the students' bodies producing movements that in turn stimulated the production of data.

The type of device observed was the same for the whole class, as noted in the participant observation process and confirmed by the following excerpt from a teacher interview: "*We purchased wearable devices that were the same for the whole class. They are user-friendly, comfortable and sturdy, equipped with a sensor to measure heart rate and the level of oxygen saturation in the blood*" (A teacher interviewed on 21/3/2019). Here, we can already see the elements of a choice that trace a path forward. Indeed, the teacher told us: "*What I told the students was that this device was a new way of accessing reality. In this experiment, in a way, it became our textbook, in the sense that it was a source of information and knowledge* [...]. *In this activity, this was the textbook for the subject we were studying*" (A teacher interviewed on 21/3/2019).

The smartwatch therefore "translated" the teacher's explicit educational-pedagogical choice not to use the textbook. "Translating" means that the device, to fulfill the teacher's aim, transforms and betrays its own functions or «program of action» (Latour, 1999a, p. 33), and at the same time, those of the teacher, giving rise to a new actor-network, the inevitable result of a mediation: the device as a textbook. In the process of the mediation the device-book involves, brings together or "composes" (Latour, 1999a) a plethora of elements, human and non-human alike, which together bring about specific actions.

As a book, the device acquired specific functions and gave rise to as many actions and procedures. For example, it became the main trace of the content of the activity done in a given subject, and indeed, its basic function was precisely that of tracking. The traces were written on the screen of the device through specific procedures, which in turn imposed and required certain times, a certain function applied to the bodies, etc. Keeping track of the contents on the device generated a series of gestures and actions that were repeated over a period of time, giving rise to a certain rhythm and a ritual that involved the whole class. In order to maintain ties, the aggregates were able to recruit new actors and actants through continuous mediation processes, translation, connection and delegation.

In the second activity it was easy to observe how the device made it possible to aggregate other technological artifacts and to foster relationships between various human and non-human elements that were added thus forming a network. In addition to contributing to the staging of a specific movement of bodies in the classroom to produce data, the wearable joined forces with other material elements as well as with the human subjects. Indeed, the collected data need to be processed and hence call into play computers and programs for the creation and display of contents. Moreover, they require applications for sharing, conversation, participation, mutual correction and exchange. In addition to these devices, other human actors also came into play such as the mathematics teacher, who verified the writing and application of mathematical functions and formulas, and the translation of the collected data into graphs and curves. Other activities were also elicited including the recounting of what was done by the students, discussion and sharing with peers, planning and reporting, explanation and checking with the teacher. "*I tried to give them the freedom to examine the aspect that struck them the most in that activity. But sometimes, there was a need for them to focus on a particular aspect, and then I also joined the discussion of their report with them from my computer and provided them with guidance for their project*" (A teacher interviewed on 21/3/2019).

The teacher, through the presence of the object, together with its position in the classroom and the presence of another object (the computer) as stable elements of the network, translated an ordered "doing" and at the same time the teacher's own idea of order and attention, by inscribing them in a specific movement. The result of this mediation and translation contributed to the performance of a certain movement and a certain order of the students' bodies in the space of the classroom, articulating through that movement a time, a space, certain subjects, as well as a rite or a rhythm through which the students and technology came into contact with one another, thus giving rise to what we call "physical education class".

Here we can observe more clearly how the agency of the object was not simply given by the characteristics of the object itself, but took on a meaning within the practice. The agency of the object was therefore displaced, distributed and transversal because it was staged by the relationships between the various human and non-human actors. This had a specific impact from a pedagogical standpoint: the educational experience became the product of a system of actions, a plot of actors and actants where acting was the outcome and at the same time the cause of an actively present, hybrid, changeable materiality, (Ferrante 2016; Barone, Ferrante & Sartori, 2014).

The observed lessons, far from being reduced to the action of learning notions, repeating formulas or plotting lines, or to the simple interaction between teachers and students, were the result of a myriad of socio-material assemblages, which articulated over time giving rise time after time to variably weak links and some obligatory points of passage (Latour, 1987; Fenwick & Edwards, 2010; 2012). For example, the correct movement to be made for data retrieval, the correct execution of operations to make apps and devices usable, the tempo to be maintained in collective online conversation, how to manage the sharing of results with teachers and classmates, can become particular nodes and assemblages of the human and non-human through which the different relationships of the network are built.

Conclusions

In conclusion, the artifacts make the difference! As we have seen, the wearable device mediated human interactions: far from being a neutral object, it was a socio-material aggregate capable of establishing specific practices and it was a semiotic artifact that articulated meanings and concentrated social discourses and worldviews. Observation and reconstruction of the object's network revealed how the device shaped the pedagogical model by rearticulating and translating it into concrete educational practices. The device and the network of which it is part contributed to create specific spaces, times, rhythms, meanings, discourses, which are nothing more than the concrete occurrence of what we call school.

The wearable device is an artifact through which it is possible to reconstruct the networks it gave life to and of which it is a part. It allowed us to trace the multiple associations between human and non-human elements, to reconstruct the mediations, and translations and traditions that it performed and staged from the moment it came onto the scene. By anchoring ourselves to the object, we were able to trace some of the steps and procedures through which it concretely articulated what happened in the school, at the level of socio-material educational practices. The object used in the case study that was examined drew attention to and aroused discussion of the body, which seemed to translate and oscillate between attention to health and control. Indeed, alongside the socio-material articulation of the network we found the articulation of signification, the effects of meaning.

Through the reconstruction of the heterogeneous relationships in which the artifact, in this case a wearable technology, participated in and in turn created, it was possible to reconstruct the networks and also the meanings that were conveyed in a given environment. The set of connections and mediations between these tangible and intangible elements, articulated with each other, combined to define particular circumstances of use, meanings, times, spaces, behaviours, experiences and learning. The technological artifact, in our case, became not only a tool for carrying out school planning, but a mediator whose analysis made it possible to reconstruct which particular practice and educational experience it performed. Finally, the observation from an ANT perspective allowed us to trace the agency of the artifact which, regardless of the intentions and the explicit didactic-educational objectives of the teacher, forced each student to take into account the presence of others, whether they be human or non-human.

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