Thinking Science through teachers' experiences with digital technologies: Toward a 'naturalistic' pedagogical landscape?

Marianna Vivitsou[1], Kirsi Tirri[2] & Heikki Kynäslahti[3]
[1]Doctoral student, [2]Professor, [3]Adjunct Professor
Department of Teacher Education, University of Helsinki, Helsinki, Finland

Abstract

In this study we draw from the interviews of four science teachers, one from Finland and three from Greece, and two science education experts from Finland in order to discuss and analyze pedagogical decisions and choices when the learning space is enriched with social networking environments, and digital and mobile technologies. Our research interest departs from concerns that technological pervasiveness generates and an observed suspension of belief in science rooted in the risks that post-industrial societies are facing nowadays. By examining the study participants' experiences, we aim to trace the intersection of science and technology with pedagogy and, in this way, to gain an insight into the possible futures of science education. The qualitative analysis of the data indicates instances of both deductive and inductive logic that show up through views of science as thinking and as method. The analysis of participants' speech also reveals recurrent underlying conceptions of science and related issues.

Keywords: science, digital technology, science educators, thinking

Introduction

As technological pervasiveness becomes more and more apparent in life and in the school nowadays, this study departs to investigate the intersection of digital technology with science education. To this end, we will discuss and analyze the pedagogical decisions and choices of a Biology teacher from Finland and three Computer Science and Technology teachers from Greece. These teachers enrich the learning space by integrating digital and mobile technologies for pedagogical purposes. In addition, we will also analyze the interviews of two Science education experts from Finland discussing the pedagogical integration of digital technologies for science education research. By examining the study participants' experiences, we aim to trace the intersection of science and technology with pedagogy and, in this way, to gain an insight into the possible futures of science education.

Our research interest is based on considerations of trends resulting from research findings (e.g., Schreiner & Sjøberg 2004, Sjøberg & Schreiner, 2005) indicating that, when it comes to science education, it is society that feeds values and attitudes toward science and technology into the classroom, and not the other way around. Certainly, we do not take a position that beliefs of science are culture-free or context-independent. What we argue, however, is that these trends are tied with a suspension of belief in science and are rooted in the risks that post-industrial societies are facing nowadays. Some examples of these are ecological hazards, global warming, dangers from nuclear, chemical and genetic technology, are made-made and are the by-products of scientific and technological advancement.

To raise student consciousness of environmental hazards curricula in Finland and Greece have introduced concepts such as environmental sustainment in the jargon of science and science-related subjects (e.g., Biology and Geography). Additionally, cross-curricular teaching hours are allocated in the school timetable. In a discussion of findings of a study that examines student values and attitudes from 75 schools in Finland, Uitto and colleagues (2011) argue that participation in school practices and learning sustainability can promote environmental responsibility more effectively than traditional instruction. We consider that the trend to extend indoor curriculum to outdoor scientific classes that we observed in our search for up-to-date themes in science education conferences correlates positively with Uitto et al.'s (2011) finding. As environmental sustainability relates to science both directly and indirectly, changes in teaching science seem but inevitable in the future.

Developments in digital technologies are also by-products of scientific and technological advancement. Another type of disbelief then relates to the digital technologies themselves. Despite the fact that digital, mobile and networking devices and environments connect individuals, they often become a world of their own that dis-connects (Ihde 1990) and, eventually, comes to undermine young people's educational achievement and time management for learning and personal growth. Obviously, teachers play a catalytic role in the ways the role of science is translated in education and in society. Science educators' thinking, therefore, presents a research challenge for us and adds to the considerations we discussed earlier.

Along with the fact that digital technologies change the ecology of the traditional learning environment these challenges seem even more pressing nowadays when it becomes more and more evident that people learn with the configurations of multiple technologies in concert. This comes as a development of what is termed by Tsihrintzis et al. (2012) pervasive computing. Pervasive computing or the third wave of computing technology allows users to interact with a variety of networked digital devices. In our study however, the emphasis is on the human element rather than the purely technological. We believe then that, in order to gain a better insight into the situation, it is important to understand how science teachers think, make decisions and act. In other words, it is important to understand teachers' pedagogical thinking (Kynäslahti et al., 2006).

By considering teachers' thinking in relation to their professional life decisions we position science teachers as 'beings-in-the-world' and, at the same time, explore the subtleties of their particular situations. This is an aspect that has been traditionally disregarded in, for example, artificial intelligence design (Dreyfus, 1992). The research need to augment our knowledge of teachers' thinking is consistent with the need expressed by Chrysafiadi and Virvou (2013) for a design of e-learning models and systems that is informed of user knowledge state and characteristics.

It remains, therefore, to look into the study participants' speech and determine whether our assumptions are confirmed, or not, and to what extent. In this way, we will seek answers to our main research question, 'In what ways do science educators use digital technologies and social media to promote science-related concepts and literacies?'

We will do so through the analysis and discussion of pedagogical decisions and choices as appear in the participants' speech and in relation to our review and discussion of the relevant literature.

Theoretical background

In this study, we hold the view that the prevailing definition of science education changes into one that blends both deductive and inductive modes of thinking in the teaching of science and technology, with technology. By this, we mean that the transposition involves an insight into (natural) phenomena and related concepts that complements an approach that relies upon laws, formulas and calculations. This way of blending a more 'naturalistic' with the core 'scientific' approach positions organically the study of science-related concepts into the living experience and enriches student learning of science with digital technologies, whether this occurs in the classroom, the school laboratory or outdoors.

Our review of the literature aims to link the discussion with theories in the natural (or physical) and the human sciences. To this end, we depart from what Polkinghorne (1983) calls the 'original debate' that asks whether the former should emulate the methods of the latter or whether the human sciences should develop their own methods. The debate was framed as a result of the commitment of natural sciences to the investigation for a theory that explains events in a clear and precise manner during a time when reality was connected to an understanding of knowledge as certainty. Since then developments of alternative systems of inquiry brought about changes in our understanding of the nature of the scientific enterprise. Inevitably, the realization came up that the debate should be refocused and methodology should bring about new conceptions of how we know and understand the world (Polkinghorne, 1983).

The 'naturalistic' stance in this study, therefore, does not draw from the 'received view' or deductive system of inquiry. Guiding perspectives (Polkinghorne 1983, 90) of the received view include: knowledge (as opposed to opinion); and the deductive logic (i.e., one generated from axiom statements and grounded in observation statements. Polkinghorne (1983, pp.56-7) uses an example from Chemistry to discuss qualitative differences that were once reduced to differences in quantitative relationships among the parts of a whole. A living thing, although it consists in chemical reactions, derives its aliveness from its particular structure, i.e., the mutually supporting ensemble of interactions. It is, therefore, through this process (i.e., emergence) that we can understand the parts in terms of the characteristics of the whole.

A study consideration results from research findings (Schreiner & Sjøberg 2004, p.5) indicating that, despite the fact that the ways students engage and relate to science in school cannot be measured, attitudinal outcomes are longer-lasting in the mind of the learner than the actual content mastered. In an international comparative study of 15-year-olds from 35 countries Sjøberg & Schreiner (2005) map out attitudinal and affective perspectives of science and technology young people bring to school or have developed at school. According to the study findings, both Finnish and Greek students agree rather strongly that science and technology are important for society. Surprisingly though, young people in both countries seem to be very reluctant to become scientists (Sjøberg & Schreiner, 2005, pp. 4, 6).

Our intention in this study is to stress out that what we need for a better education is a deeper understanding into people's values and beliefs, or in other words, insights into the ways people involved in the educational situation interpret reality. In the same way, we need to understand what they think of technology in pedagogy.

The prevalent account of technology as means to an end is rooted in the explanation of technology as an act of human artifice. This instrumental account points toward one end: humans should try to master technology and use it in the most profitable manner (Heidegger, 1977). In his work Heidegger attempts to capture the essence of technology as a way in which truth happens (Riis, 2010, pp. 125-6). According to Riis (2010), this is where the interest in Heidegger's philosophy of technology lies in, i.e., in seeking answer to the question: 'How does the world appear when disclosed through modern technology?'

The essence of modern technology prepares nature to stand at command and be able to deliver what is ordered from it (Heidegger 1977, 320). Following this, the world is captured in terms of a resource that must be describable in quantitative terms that make resources easier to count and control (Rriis, 2010, p.126). The technologically disclosed world is potentially controllable object and so everything in this framework appears as something, as object rather than subject, Riis argues. What humans fail to notice is that in this disclosure of the world they are themselves treated as resources that produce and secure even further resources. It is not enough, therefore, to take technology at face value. What technologies actually encourage us to do is to reason in terms of ends, means and objects. According to Heidegger, this is calculative reasoning, or thinking.

Considering pressing needs for changes in the way we think and act upon the world, we agree that calculative thinking is not enough. What is significant nowadays is to consider how education can best respond to the responsibilities and requirements the current era generates. The latter are tied with notions such as responsibility for other humans, other species and the environment, and respect for otherness. As such, they are also intertwined with the aims and goals of science education. Our insights from research in pedagogical mediated publics (i.e., where teaching and learning experiences are enhanced with social networking and digital technologies; Vivitsou et al. forthcoming) indicate that a space opens up for learning that builds upon human relations in an ongoing, interpretive dialogue. In this technologically enhanced space young people connect with peers and construct knowledge also by developing an understanding of not only natural environments but of the objects and the activities found in these.

Following the inductive logic as discussed in Polkinghorne (1983, pp. 108-9), through the analysis of the participants' talk we aim to discover the values that are held to be true by them, as members of the science educators' community. In accordance with the principles of induction, we do not aim to generalize across a population. What we aim, however, is to generalize across the phenomenon, which, in this study, is located at the intersection of science and technology with the pedagogical thinking.

The Study

Aims & methods

To achieve the aims of this qualitative study we will discuss and analyze the content of data resulting from semi-structured interviews. In these, the Finnish and the Greek science teachers discuss their experiences of integrating digital technologies, and social networking environments in teaching science and related subjects. Through content analysis we aim to gain insight into the participants' views and to offer valid research outcomes.

The context and the participants

As we mentioned above, in this study data sets result from semi-structured interviews that cover 3 phases of collection. The first is held in May 2011 and involves two one-hour long discussions. One with a female Biology and Geography teacher from an upper secondary school in Helsinki, Finland and another with a male Computer Science teacher in Northwest Greece. Both respond to questions about the ways they integrate web-based and digital environments and tools into the pedagogical practices for learning. The interview reveals the need for the Greek teacher to circumvent limitations imposed by the lower secondary Computer science curriculum. In this way, the teacher deals with issues relating to obsolete content of learning and insufficient subject teaching time.

By running after-school, project-based activities and integrating seventh with eighth and ninth graders, this teacher and his colleagues work on a voluntary basis and, eventually, construct a 'parallel', flexible curriculum. Participation depends on student choices among themes that draw from human and natural sciences, is technology enhanced and uses digital environments for real time and asynchronous communication with students and teachers from different locations. Considering this, we decided to hold a second round of interviews in the following year (October 2012). In addition to the Computer Science teacher, the group of study participants is enlarged with his volunteer colleagues, a female Technology and a male Computer Science teacher. They were interviewed separately for approximately 20 minutes each and questions were more focused on whether technologies can fail the overall teaching plan; how this can be amended; and what this whole pedagogical scheme means for students and the learning process, as well as for the teachers' professional development.

The final round of data collection takes place in November 2013 and involves two female science education experts at the University of Helsinki, one postdoctoral and one doctoral researcher. The interview comes, in reality, as an informal discussion between three colleagues, i.e., the Finnish researchers and the lead author where the former elaborate on the experience of design and research into learning Physics and Chemistry with digital and mobile technologies in two primary schools in Finland. Water, air and motion are the natural phenomena under investigation. Interview questions mainly ask about the ways science teachers teach science nowadays, how technology and networked spaces enhance student understanding of scientific concepts and in what ways the latter engage in digitally enhanced activities.

Overall, Table 1 below shows the study participants and the technologies they use to teach or study teaching and learning science and science-related subjects:

Table 1. Participants, year of interview, technologies & learning content

Study participants (N= 6) / Year of interview	Technologies & content of learning
SCIE Fi T1 (Science, Finland, Teacher 1/2011	This female teacher uses social networking environments to teach Biology and Geography in an Upper Secondary School, Helsinki.
SCIE Gr T1 / 2011, 2012 SCIE Gr T2 / 2012	These male teachers work with two thematic student groups. One examines illusions and dangers hidden in social networking. Another looks into environmental hazards and possible solutions for sustainability (Lower secondary, Northwestern Greece).
SCIE Gr T3 / 2012	Like her colleagues, this female teacher uses networked spaces and digital and mobile technologies to teach Technology and to look into Human Relationships with a group of students. The students read books, discuss ideas and, in order to express their emotions and tell stories with posters and pantomime in project-based after school activities (Lower secondary, Northwestern Greece).
SCIE Fi Xp1 / 2013 SCIE Fi Xp2 / 2013	These female Science education experts use technologies to study teaching and learning Physics and Chemistry with digital and mobile technologies in 2 Finnish primary schools.

Findings and Discussion

The analysis reveals two focused concepts. In one science comes up *as way of thinking*. In another science is *method* that links with digital technology. Digital technology, therefore, appears as science used for the teaching of science or related concepts and literacies. Also, there is a third concept recurrent in the participants' talk and becomes evident where the discussion brings forward the *underlying conceptions* or the meanings they attribute to science and related issues. We will discuss these further in the following sections.

Science as Thinking

In this study, Science as Thinking seems to be a theme in the talk of, almost exclusively, female participants. As categories emerge through the analysis of interviews, the Finnish teacher's statement that knowledge building is a movement from the whole picture to details expresses a pedagogical belief on the one hand. On the other, the scientific stance for synthetic and analytical thinking also comes up and relates with the need for teaching natural phenomena as a whole, '*not just objects*', as Xp1 explains. To further delineate the argument, Xp1 presents her view of learning science as starting from the qualitative sense of the phenomenon and ending up with the quantitative aspect. This is a perspective that Xp2 seems to support as well. In addition, knowledge construction in science requires experimentation, measurement, gathering data and deriving rules instead of using calculations and mathematical formulas. Science is goal-oriented, takes hard work and creates tensions, as both Xp1 and Xp2 strongly argue. The Greek T3 seems to be thinking along similar lines. This relation shows up in T3's argument that it is hard for students to translate '*scientific knowledge into practical thinking about space and time*'.

At this point a number of oscillating pairs also appear. One lies in what Xp2 terms as '*divide in teaching science*' where the need for learning with experiments is faced with established practices of teaching and learning science with the book. In Xp1's view, the latter can explain students' pre-conceptions of what learning science is. According to Xp1 and Xp2's observations, high-achievers consider learning science with technologies as '*waste of time*'. As Xp2 elaborates, '*Learning the rules from the book and listening to the teacher was good for them. They found this* (i.e., learning with videos) *was more complicated*'.

Another oscillation starts with the statement that science is everywhere in daily life. As Gr T3 explains, the theory of relativity lies behind every single activation of a cell phone's GPS system. And yet, despite this notion of science 'everywhere', T3 negates the previous statement with the argument that it is too hard for students to grasp what '*vulgarization of science really means*'. It seems, therefore, that, although all around, science is not for all. The notion of science as hard work (i.e., the one introduced by Xp2 and supported by Xp1) corroborates the view posed by T3. As Xp2 argues, young people become less interested in science at about the age of 12 when study becomes more and more cognitively demanding. On the other hand, young female students seem unprepared to successfully deal with fear for labs and experiments. We trace a similar view about women in science in the literature. As Nussbaum (2000) argues, women 'lack opportunities for play and the cultivation of their imaginative and cognitive faculties' and 'fewer opportunities than men to live free from fear'. However, as the arguments link decrease in interest with age and gender, in addition to the requirement for hard work, science seems to become more and more exclusive.

The notion of 'hard work', extrapolates onto the field of humanities. As Xp1 explains, although we need '*imagination and creativity when doing some kind of lab works ... we also need hard work while doing those. And it takes time to do this homework, i.e, calculating results'.* According to Xp2's view, '*It takes some effort to learn, repetition and practice in different sort of ways than in humanities*'. While another opposition shows up between natural and human sciences, imagination and creativity seem not to be part of the hard work equation.

Ultimately, it seems that, in our study participants' view, abstract thinking required in science equates with thinking analytical and calculative and is separate from thinking imaginatively and creatively. The latter seems to be left for the humanities where things are easier, since they have long been divorced from science. This notion possibly explains the Greek T3's shift from the language of science to that of emotions. As T3 claims, it is an attainable goal to aim for student gaining insights into literature rather than into the abstract history of Technology.

In the definition of her identity as scientist the Finnish teacher points out that, in addition to an adherence to facts, she also cares not to feed own values to students. This remark actually brings forward the opposition between the value free nature of sciences and the value laden-ess of humanities. It also brings forward that, eventually, the study participants seem to be neither value free nor theory free.

Science as Method

It is surprising how absent the notion of science per se is from Greek male teachers' speech. Both are Computer Science teachers in lower secondary education where the one-hour weekly time allocated has consequences not only on how the teachers view the content of learning but how they perceive their own position in the school as well. Teachers who specialize in Computers and Technology, like T1, T2 and T3 do, are frequently faced with work and travel to more than two schools in distant areas. In a sense they are 'teachers on-the-go'. It only comes natural that T2 categorizes the subject as second-rated in comparison to others more favored in the curriculum. One way to extend allocated time is by organizing after-school programs with student participation on voluntary basis. The programs involve inter-institutional, home and international partnerships and relations that are enhanced with web-based and digital technologies.

All study participants view social environments and digital technologies as spaces for student growth and development. The Greek teachers, mainly the male ones (T1 and 2), discuss these as spaces where opportunities open up for students to build and strengthen relationships with peers from other schools and countries. This approach attributes an interpretive property to technology. In this sense, student connecting with peers is a meaning making process, by becoming familiar with peers' everyday lives, what their views on specific subjects are etc., in web-enhanced discussions or through digital stories. In this way, students get to know peers and their cultural landscapes.

One after school theme concerns the environmental problems and risks the area is faced with. Another aims to enhance student understanding of illusions hidden in social networking sites. As both plans link with the teachers' background field, it is evident that opting for science-related topics is no accident at all. They combine this with a 'human relationship' oriented approach. As T2 argues, they (i.e., teachers) want to share views and opinions with students, in order to better understand how they think and feel about things. T1 argues that changes in, particularly, marginalized student attitudes toward schooling are visible. Developing a sense of responsibility, working in groups, learning and using technologies as pathways for communication seems to be the key of success in terms of student involvement. Although T3 does not overtly take this stance, her participation in the scheme points toward the same direction.

The Finnish experts also take a stance in favor of the view of 'digital technologies for learning that draws from cultural landscapes toward improved human relationships'. This becomes more obvious when Xp1 stresses out how important it is '*that learning science goes to their home and discuss with parents and siblings and friends*'. In this way students can learn not only through cables, says Xp1. Although this dimension is conflicting with the Greek view of building relations through cables the bottomline is more convergent than divergent: human relations do matter when learning about or with science.

Similarly, the Finnish teacher expresses a view of networked technologies for growth and development, and as ways to enrich the content of learning and keep up with rapid scientific progress and science-related discussions. Moreover, social sites, such as blogs, can accomodate provocative ideas. However, her background as teacher in Upper secondary seems to pose time limitations and imposes a priority for subject-centered material coverage. Building identities in Upper secondary seems to be entrusted to popular sites that create space for students to socialize and grow there.

During the discussion, the Finnish teacher's scientific background in Biology becomes visible while she stresses out how important it is to keep with 'facts'. In this sense, the Internet infrastructure blurs the limits between what is essential, or fact, and what is not, which allows the teacher's skepticism to show up. She is not alone there. The Finnish experts bring forward the challenges of pedagogical integration of digital technologies, a point where especially the Greek male teachers are in agreement. Although launched from different kick-off points (e.g., reliability of information, bandwidth, software compatibility and update etc.), invisible systems of technology, like Pandora's box (Vivitsou et al., forthcoming), seem to package both hopes and fears into the experiences of the study participants.

Professional development, in terms of teaching science and using technologies to teach science, seems to be 'dark matter', a nowhere-leading path, for almost all. For the female Greek T3, it works for planning a state-of-the-art lesson, but, how students grow in the process, remains an issue. The male teachers are not very optimistic either. Other than becoming familiar with people from other cultures and perspectives, they do not see much personal learning or development taking place. The Finnish teacher does discuss practices with colleagues in the natural sciences but teaching science per se is like recipe to her. One of the Finnish experts (Xp2) expresses the view that teaching with technologies can enhance learning by video recording and observing the process.

Conclusions

Overall, it seems that the science educators' thinking reflects instances of deductive logic, in the sense that they view science connected with regularities inferred axiomatically within a frozen universe (Polkinghorne, 1983). The view, however, of mediated publics as spaces where getting connected with peers enhances development and growth through an aesthetic appreciation of the world frees the view of technology from the instrumental approach to technology (Heidegger, 1977; Riis, 2010). As teachers use digital environments to create opportunities for learning science and science-related concepts by building relationships and communicating with others, they also attribute an interpretive property to technology (Ihde, 1990).

This kind of learning does not aim for the ideal of certainty. On the contrary, it builds knowledge gradually as young people gain insights through the multiple interpretations of peers' and own cultural landscapes. As this view reflects the logic of argumentation that supports the conclusion-making process, it indicates an instance of inductive reasoning. Anyway, as Polkinghorne (1983, p. 128) puts it, although 'there is no hope for eliminating all error' in order to reach the ideal, an agreement between what constitutes belief and reality can be reached through experience, in a process of negotiation with others of what the real is over time.

In addition to instances of inductive and deductive logic, teachers' talk presents underlying conceptions of science. These are made visible where, among others, the decreasing interest in science is related to age and gender, where a pessimistic view of development as scientist–educator shows up and where imaginative and creative thinking is seen as separated from hard work and the sciences. We believe that these conceptions, as expressed by the teachers, disclose wider socially rooted biases. As such, these phenomena generate new research challenges and call for further investigation.

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