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Teacher Students' Critical Thinking Skills Using the Concept of Disruptive Technologies

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Critical thinking is fundamental to 21st century learning and has thus become an important part of the technology curricula in many countries. Critical thinking draws on the ability to examine, analyse, interpret and evaluate, as well as asking questions and participating in discussions about risks and benefits of different technological solutions. An important task for teachers is to support young children in developing these skills. Students on a Swedish primary school teacher education programme were given an assignment inspired by the concept of 'disruptive technologies' (Barlex, Givens & Steeg, 2016; Manyika, Chui, Bughin, Dobbs, Bisson & Marrs, 2013), choosing from one of nine disruptive technologies and searching for information. The list was created on the grounds that these are technologies that are likely to have a significant effect on the students' lives in a not too distant future. Based on the information found, the students were to critically analyse the technology they had chosen. This case study was performed through a thematic analysis of 120 assignment texts. The analysis showed that some of the suggested technologies were chosen more often than others. Autonomous cars came top, although robots in elderly care were the most frequently chosen technology among female students. The students performed well in the searching and collecting process. They found information about pros and cons for their chosen disruptive technology. However, the analysis also showed that the students had difficulty evaluating and problematising the information they had found. In their conclusions they did not change their original point of view. Even though they found more negative aspects of a new technology, they accentuated the positives.

Key Words: Technology education, Critical thinking, Technological literacy, Disruptive technologies, Teacher students.

1. INTRODUCTION

There is growing concern about whether today's learners possess the combination of critical thinking, creativity, and collaborative and communication skills necessary to be able to tackle the unexpected developments they will face in the future (Scott, 2015). Due to the emergence of increased attention to the competences required for the knowledge society, especially digital technologies, there is a call to update educational systems (e.g., European Commission, 2018; Voogt & Pelgrum 2005). Educators, as well as representatives of education ministries, governments, foundations, employers and researchers, often refer to these abilities as *21st century skills* (Scott, 2015). But even if the term is widely used, there is no single framework for what it means or what knowledge is required for these skills (Anandiadou & Claro, 2009). However, from an analysis of curriculum and assessment frameworks for 21st century skills around the world, some of the most frequently named skills are communication, creativity, critical thinking and problem-solving (see e.g. Care, 2018; Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci & Rumble, 2012; Voogt & Roblin, 2012).

Even if it is difficult to predict what knowledge and skills future generations will need, we can assume that technological literacy implies that both today's and future citizens are able to make well-informed, wise judgements about various aspects of technology, and to compare evidence, evaluate competing proposals and make responsible decisions. Without this kind of knowledge they will not be able to make deliberate democratic choices (Garmire & Pearson, 2006; Keirl, 2006).

From a technology education perspective, it is clear that education cannot be expected to teach students how all contemporary (or future) technologies work. That means that a 21st technological literacy involves more than the ability to create technological objects or to use or understand the function of certain technologies – students

also need to develop their critical thinking skills and be open to seeing the technological world from multiple perspectives (Axell, 2017a; 2017b; Dakers, 2011; Petrina; 2000; Williams, 2009).

1.1. Technological Literacy and Critical Thinking

The aim of the school subject of technology is that students learn to understand and act in a responsible way in the technological culture they are a part of. Due to the ubiquity of technology, an understanding of what it is, how it is created, and how technological choices shape society as a whole, is important for democratic and well-informed citizenship. How well citizens are prepared to make these choices depends largely on their level of *technological literacy*. According to Garmire and Pearson (2006), technological literacy can be described as having three major dimensions: 1) *knowledge*, 2) *capabilities*, and 3) *critical thinking* and *decision-making*.

However, even if the concept of ‘critical thinking’ is widely used within educational discourse, there is no uniform framework for what it means or what knowledge is required for these skills (Anandiadou & Claro, 2009). Nevertheless, Ennis (2018), a leading researcher on the concept, describes critical thinking as a “reasonable reflective thinking focused on deciding what to believe or do” (p. 166).

What characterises a person with highly developed critical-thinking and decision-making skills is, according to Garmire and Pearson (2006), that when “confronted with a new technology, he or she asks questions about risks and benefits and can participate in discussions and debates about the uses of that technology” (p. 2).

Dakers (2011) agrees with Garmire and Pearson when he states that to be able to create conditions of understanding for the modern technological world we live in, the technology curricula in many countries must place more emphasis on issues relating to values and attitudes in terms of technology, such as ethics, environmental impact, social impact, sustainability, and the interface between humans and their active involvement with technologies. Dakers’ conclusion is that a more philosophically oriented pedagogical framework is thus needed.

Petrina (2000) also emphasises the importance of a critical perspective in technology education. He calls for the development of a *critical technological literacy*, which he describes as “a critical engagement with, and appropriation of, the built world and its signs of the times, the use of critical discourses, genres, or language to confront that world, and the mobilisation of resources to politically transform what’s built” (Petrina, 2000, p. 201).

However, this is a challenge since the main focus of technology education still tends to be on developing knowledge relating to the fabrication of artefacts, and not on developing a critical awareness of the technological world young people inhabit; how it shapes their lives and will shape them in the future (Dakers, 2006). Additionally, previous technology education studies show that many students lack the ability to make a critical assessment of technology and rather act as spectators or uncritical consumers of technology (de Vries, 2005).

1.2. The Swedish Context

As a part of ‘the waves of change’ in education, the Swedish Government commissioned the National Agency for Education in 2015 with drawing up guidelines for an updated national strategy for the Swedish school system. One part of this work was to revise the curriculum for primary and upper secondary education. In the revised curriculum (2017), digital competence is visible throughout the curriculum, but is explicitly formulated in some specific subjects: technology, mathematics and social studies (Heintz, Mannila, Nordén, Parnes & Regnell, 2017; Swedish National Agency for Education, 2017). Under the heading “Fundamental values and tasks of the school”, it is stated that schools should help students to develop an understanding of how digitisation affects the individual and societal development (Swedish Agency of Education, 2017, p. 9). In line with the changes in the curriculum, teacher education courses are undergoing revisions.

Based on these revisions, the aim of this case study was to examine teacher students’ critical thinking skills by examining an assignment on the concept of ‘disruptive technologies’ (Barlex, 2017; Barlex, Givens & Steeg, 2016; Manyika, Chui, Bughin, Dobbs, Bisson & Marrs, 2013). Barlex (2017) justifies the concept in

technology education by stating that it is important for young students “to engage in critique of technology particularly with regards to those technologies that might have a significant effect on their lives” (p. 233).

The participants originated from two student groups: the undergraduate programme for teaching in preschool class and grades 1-3, and students from the undergraduate programme for teaching in grades 4-6. The technology course is mandatory for students studying to teach preschool class and grades 1-3, while the technology and science courses are elective for students studying to teach grades 4-6.

2. METHODS FOR COLLECTING AND ANALYSING DATA

2.1. A Description of the Assignment

As an introduction to the assignment, the teacher students were told that there is often a reliance on new technology, especially among young people. The things we call technologies are ways of building order in our world – they are powerful forces that give meaning and direction to our lives. Power conditions, authority, freedom and social justice are often deeply embedded in technical devices and systems (Winner, 1986). When a new technology emerges, it opens up new possibilities for human activity and interaction. Although it may not be immediately apparent, some technologies have a huge impact on society and noticeably change people’s activities and interactions. Such technologies can be described as ‘*disruptive technologies*’ (Barlex, 2017; Barlex et al., 2016; Manyika et al., 2013).

The students were then given the task of choosing one of nine technologies categorised as ‘disruptive technologies’ and searching for information. The list was created on the grounds that these technologies are connected to digitisation and are likely to have a significant effect on the students’ lives in a not too distant future. This was an individual written assignment, and the students were asked to choose one of the following technologies:

- The ‘My Doctor’ app
- ‘Swish’ (A Swedish mobile payment system)
- Autonomous cars
- Electric cars
- Drones (civil and military)
- The Internet of Things
- Wrist chips
- Robots in elderly care
- Digitisation of education

Based on the information found, the students were asked to critically analyse the specific disruptive technology they had chosen. The different steps of the analysis were based on Barlex et al.’s (2016) Teacher’s Guide and the McKinsey Global Institute’s descriptions of ‘disruptive technologies’ (Manyika et al., 2013) .

The first step was to discuss the chosen technology based on four criteria:

- It “upset the status quo”
- It changes the way people live and work
- It reorganises financial and social structures
- It leads to entirely new products and services

The next step was to put the specific technology at the centre of a “winners and losers target chart”. The individuals or groups that are directly affected by this technology should be placed in the first circle, and those indirectly affected in the second. The students were also asked to identify ‘winners’ and ‘losers’ among those affected and colour them in two different colours, describe them and explain why they were designated thus.

They should then take a stand: first argue from the perspective of the ‘winners’, and then argue for the ‘losers’. This should end with a final analysis of the chosen technology, including the following perspectives: historical, gender, sustainable development, societal and global perspectives.

The final step was to write a suggested application of the idea of ‘disruptive technology’ for primary education (ages 6-12). What kind of disruptive technology can be subject to analysis in a primary technology classroom? How could the ‘disruptive technology’ approach be used in the classroom? Why is this specific ‘disruptive technology’ a good choice for an analysis with children?

2.2. The Analysis

Barlex, Givens, Hardy and Steeg (2016) used the concept of ‘disruptive technologies’ in a case study with trainee teachers. Their focus was on the students’ ability to identify whether a technology was disruptive (Manyika et al., 2013). Our students were also asked to argue for the disruptiveness of their chosen technology, but our focus was on their ability to identify and analyse ‘winners’ and ‘losers’ connected to the application of a chosen technology.

The study was performed through an analysis of the students’ assignment texts and based on Braun & Clarke’s (2008) description of the thematic analysis process, which includes the following steps: reading and re-reading texts, systematically coding, searching for themes, defining themes, and finally summarising the patterns found and discussing the themes identified in relation to the aim of the study.

However, although all the assignments were analysed, in this case study we only present the results of the thematic analysis of the most frequently chosen topics for female and male students.

3. RESULTS

3.1. Topic chosen

Our analysis shows that the students found some topics in the list more interesting than others.

Topic chosen by (n)	Male students (18)	Female students (102)
Autonomous cars	37%	20%
Robots for elder care	5%	33%
Digitisation of education	26%	12%
Drones	11%	5%
Swish cell phone pay service	5%	6%
Electrical cars	5%	5%
Microchip implants	0%	14%
Internet of Things	5%	0%
My Doctor Online	0%	5%

Since autonomous cars were the most frequently chosen topic by both female and male students, we chose to carry out a thematic analysis of their responses. Through our analysis, we identified two overarching themes: *contradictions* and *over-reliance on technology*. Within these themes, we also identified a selection of sub-themes, illustrated here with quotes from the students’ texts:

3.2 Contradictions

Economic aspects

“Producers of cars and car rental companies are winners”

“The cost of transportation will be lower for individuals”

“More people will be able to go by car”

“The number of cars will be greatly reduced”

“Professional drivers will lose their jobs”

“There will be many jobs for programmers and engineers”

Environmental aspects

“The number of cars will be greatly reduced”
“More people will be able to go by car”
“The cars need no parking spaces – they will circulate”
“When there is no need for parking spaces, there will be more green areas and parks”
“Autonomous cars are good for the environment, as people will be able to co-travel”
“Kids can use these cars by themselves”

Social impact

“We will have more time for social activities with family and friends”
“Children can transport themselves to school and leisure activities”
“Elderly and disabled people will be able to travel by themselves.”
“Elderly and disabled people are dependent on help from others/a driver when travelling by car”
“There are more negative aspects than positives of autonomous cars in the information found, but the positive aspects outweigh the negatives anyway”

3.3. *Over-reliance on technology*

Lack of risks

“Autonomous cars are designed not to crash into people or things – they are safer than human drivers”
“The sensors in combination with AI make it impossible for these cars to crash”
“You can go by car with other people who are going to the same place”

The perfect technology

“The autonomous cars can be hacked – but that problem will be solved by safer systems”
“Responsibility in case of an accident is a problem – the laws have to be changed”
“Automated cars have 30 sensors, which means they can make the best decisions”

4. DISCUSSION

Based on our analysis, we note that some of the suggested technologies were chosen more than others. Autonomous cars came top, although “robots in elderly care” was the most frequently chosen technology among female students. Male students were more interested in the technology itself and female students in safety, health and the individual impact of a new technology. As previously noted, Sweden is about to change its national curricula and will have more digital competence, computer science and programming from grades one to nine, and this was also met with high interest by the students.

The students usually worked well in the searching and collecting process, and found information about the pros and cons for all their topics. They also mentioned the sources they used, and to some extent were alert to alternatives, and able to identify risks and benefits (Ennis, 2018; Garmire & Pearson, 2006).

What the students found difficult, however, was critically analysing, problematising and evaluating the information they had found. For example, they did not change position even if the evidence or reasons were insufficient (Ennis, 2018). Their conclusions seemed to be their original point of view. Even if they found more negative aspects of a new technology, they accentuated the positives. In their conclusions, they referred in particular to:

Efficiency: Autonomous cars would make “stressful everyday life” easier: things would be faster, smoother and less expensive, and people would have more time “to do other things”.

Equality: More people will be able to use cars, for example children and disabled people. Gender was mentioned, but in the argument that since there is a perception that women are inferior drivers, autonomous cars will contribute to more gender equality, since no one will be driving a car.

Security: The autonomous cars are safer than human drivers, since cars controlled by robots “cannot crash”, and the danger of tired drivers or drivers affected by alcohol would disappear. The danger of hacking was

discussed, but the conclusion was that this is a problem that will be solved by engineers. Ethical and moral problems related to accidents would also be solved by engineers – the cars “will be programmed to be ethical”.

Environmental arguments were used by almost everyone, sometimes with a naive belief that traffic volumes would be greatly reduced and that a fleet of cars always moving around would be climate friendly. Almost all students were very confident that technology will never fail. Even though they read articles discussing problems with software bugs and possible sensor failures, they strongly believed that “the car is designed not to crash”.

We do not know why the negative aspects that the students identified had so little impact on their conclusions, but some possible explanations could be:

- 1) A general reliance on technological development: they view technological development as autonomous, i.e. it ‘lives’ its own life and is something that they as citizens can have little or no impact on.
- 2) The students do not differentiate between the credibility of different sources. Popular journals, news media and information from YouTube, radio and TV shows and scientific papers were mixed and given the same value in their analysis. Maybe they understood their task as simply collecting and showing, like a scientific review of what had been written about the topic chosen.
- 3) The students thought they were expected to ‘please’ – if they participate in a course in technology, they are expected to have a positive attitude towards all kinds of technology.

In relation to critical thinking and technological literacy (Dakers, 2011; Garmire & Pearson, 2006; Petrina, 2000), it was clear that the students did not have the skills to analyse the technology from a wider societal perspective or critically analyse the driving forces behind technological change. For example, very few students had a system view of the consequences of a world with autonomous cars. Philosophical discussions about ethics and morality (Dakers, 2011; de Vries, 2005) were also conspicuous by their absence.

In summary, the students’ texts can be interpreted as expressions of a deterministic view of technology, as expressed by one student: “The losers are those who do not follow the development.”

5. CONCLUSIONS

To summarise, the task was very much appreciated by the students – they put a lot of time into the task and wrote long reports. However, due to the results of this study we will make some changes in the course design. The students will be able to learn more about technology failures; components, sensors, software bugs and computer hacking. Likewise, we are considering using a more philosophically oriented framework (Dakers, 2011; de Vries, 2005). We will also try some of the ideas Barlex et al.(2016) propose, for example making the students identify with an individual using or trying to use a new technology: An elderly person without a smartphone in an online society, a blind boy in front of the McDonald’s self-ordering console, and other similar situations. By taking the role of an individual, they may be able to take a stance. Letting them write a dramatic show or make a video is another way of examining their findings. We are also considering cooperation and integration with subjects like drama and language. A debate where students argue for or against a specific technology might make them analyse and problematise what they have read, since they have to counter other students’ arguments.

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