A balancing Act – Perceptions of how Teachers in Norwegian and Mathematics combine Digital and Analogue Devices

Sabine Wollscheid
Senior Researcher, Nordic Institute for Studies in Innovation, Research and Education
sabine.wollscheid@nifu.no

Cathrine E. Tømte
Research Professor, Nordic Institute for Studies in Innovation, Research and Education

Henrikke Flittig-Aardalen
Phd Candidate, Department of Educational Science, University of South-Eastern Norway

Karin Vaagland
Phd Candidate, The Fafo Research Foundation

Frida Vennerød-Diesen
Senior Researcher, Nordic Institute for Studies in Innovation, Research and Education

Abstract

Focusing on the teacher perspective, this article explores how teachers perceive their use of analogue and digital devices (Chromebooks) in classrooms with one-to-one coverage of digital devices for students. We study the subjects Norwegian and mathematics. Interview data of teachers and classroom observation data were collected longitudinally, at three different points in time, at one lower secondary school in Norway. Combining an inductive and deductive strategy, for each subject we found three teacher perspectives on the continuum, from being analogue oriented, to balanced, to digital oriented. Overall, findings reveal that both digital and analogue devices are used, and are perceived as useful in combination, in both Norwegian and mathematics. Teachers in mathematics do however appear to have a somewhat stronger preference for analogue devices. Further, our data illustrate that digital and analogue devices are perceived as complementary, and are used in a balanced or critical way by professional, digitally competent teachers. These teachers also demonstrate clear class leadership including engaging in conversations with their students. In general, we get a more valid picture of the actual phenomena on how analogue and digital devices are used in the classroom over time, with respect to first-order changes and second-order changes for teachers in mathematics and Norwegian. Drawing on data from the specific context of one lower secondary school, we provide some implications for further research.

Keywords
analogue devices, digital devices, teacher perceptions, case study, subject differences

Introduction

Digital change has been impacting upon societies for some decades, and schools have been increasingly integrating digital devices for learning – here defined as portable computers – at different paces (e.g., Elstad, 2016; Islam & Gronlund, 2016).

The aim of this article is to explore how teachers perceive using digital and analogue devices (e.g., pens and paper) in class, where students have their own digital device. Previous studies on how teachers combine and perceive such devices have used mostly cross-sectional and single case design (e.g., Beckman, Bennett, & Lockyer, 2014; Åkerfeldt, 2014); only a few have used longitudinal design to study change. Doron and Spektor-Levy (2018), for example, found both positive and negative changes in teachers' commitment to the implementation of digital devices for each student. Comparing the use of analogue and digital devices for teaching, scholars often neglect the specific role of teachers as mediators for learning, despite clear evidence that teacher characteristics matter for student learning (e.g., Blömeke & Olsen, 2019). Besides, school subjects differ in their epistemology, with implications for teachers' choice and use of digital and analogue devices. For writing and reading instruction, research points in favour of using a mix of digital and analogue devices (e.g., pens and paper) for different purposes, such as note-taking and memorizing (Berninger, Nagy, Tanimoto, Thompson, & Abbott, 2015; Santangelo & Graham, 2015).

The implementation of new technology often refers to 'first order' and second order' barriers. The former is about external barriers, such as lack of access to the right equipment and knowledge of how it works, while the latter is about cultures, attitudes and motivations for adopting new technology, and is often difficult to overcome (e.g., Rienties, Brouwer, & Lygo-Baker, 2013). Change can also be understood as a two-step process: 'First order change' means doing the same, but with a new technology, and 'second order change' implies that the activities themselves are redefined. While the former might comprise relatively simple processes to optimize established practices, the latter involves the introduction of radically new practices replacing the old. To succeed, the school principal plays a role in initiating different understandings of what digitalisation means for pedagogical practice (Genlott, Grönlund, & Viberg, 2019).

Studies of the use of digital devices in classrooms with one-to-one coverage provide many examples, mostly of first order changes (e.g., Gilje et al., 2016; Igland, Skaftun, & Husebø, 2019). For a lower secondary school in one municipality, Igland, Skaftun and Husebø (2019) found that digital devices were used during about half of the instruction time, and that they were used mostly in Norwegian and other languages, least in mathematics. Thus, digital devices had become a natural part of students' and teachers' everyday lives. This study, however, was limited to the teachers' discourse on the importance of digital devices in their own classrooms.

This article, however, addresses the use of digital and analogue devices in combination, more specifically, the relationships between teacher perspectives on how they adapt such devices in Norwegian and mathematics. Drawing on data from a longitudinal evaluation study in one municipality, which implemented the device Chromebook, it aims to describe similarities and differences in how teachers in the two subjects Norwegian and mathematics perceive using digital and analogue devices in class.

Given an increasingly integration of digital devices in schools (Olofsson, Lindberg, Fransson, & Hauge, 2015), and evidence on the benefits of analogue devices for learning (e.g., Mangen, 2018), we address the following research question: How do teachers in one lower secondary school perceive using analogue and digital devices in mathematics and Norwegian, and do their perceptions change over time? Choosing Norway as a country context,

denoted as 'early adopter' (Rogers, 1995) of digital innovations, our study is ground-breaking, as it addresses the complexity in combining different devices in class by using several data sources over several points in time. Thus, it contributes to international research on teachers' use and perceptions in combining analogue and digital devices in class and changes over time.

When speaking of 'a balanced way' we mean that teachers combine analogue and digital devices in a purposeful way. That means that teachers decide to include digital devices in their teaching as one of several resources to hand, to promote variation for their students.

Theoretical background

Our choice of three theoretical perspectives was informed by the research question.

First, the socio-cultural perspective focuses on social interactions and how humans use cultural artefacts in learning processes (e.g., Vygotsky, 1978). Drawing on the idea that humans learn and develop themselves in interactions with other humans and artefacts, this perspective explores how human actions are situated in cultural, historical, and institutional practices (e.g., Säljö & Moen, 2001). Communication is supposed to draw on common ways of using language and thinking by social practices and using different cultural devices (Mercer & Littleton, 2007), and human higher mental functions and actions are assumed to be mediated by artefacts (e.g., Vygotsky, 1978), that is, man-made resources. These mediated artefacts, for example, solve problems or translate information comprising language (e.g., dialogue language; body language), signs (e.g., letters) or devices (e.g., laptops, book) (Säljö, 2001). In learning situations, mediated artefacts might impact human actions in an essential way (Wertsch, 1991). It is crucial that teachers reflect carefully on which artefacts to choose, and in which way these should be used in current situations (Säljö, 2001). As such, digital devices provide several possibilities for pedagogical purposes, for example dialogic engagement among students (Wegerif, 2007). Mercer and Hodgkinson (2008) state that social dialogue in class is crucial for developing understanding and constructing knowledge. Characteristic of such dialogue between teacher and students is active and constructive participation, building on mutual perspectives. In this dialogue, the teacher plays a crucial role as facilitator, modelling the use of digital devices.

Second, school subjects and their associated disciplines differ in their epistemology (i.e., how knowledge is structured), distinguishing between mathematics (hard) versus Norwegian (soft). Hard disciplines are characterized by an epistemology supposed to be accumulative, highly structured and with clear boundaries, soft disciplines by an epistemology that is non-accumulative, open and without boundaries (Becher & Trowler, 1989). Drawing on this distinction, we will explore similarities and differences in teacher perspectives for these two subjects. Earlier research has shown that digital devices are primarily used for writing in language subjects (Igland, Skaftun and Husebø, 2019). We assume that the subject epistemology has implications for teacher choice of analogue and digital devices.

Third, teachers need opportunities for professional development (Postholm, 2012), that is, to learn how to use and to combine different devices in a competent manner. Being digitally competent means to have various skills (e.g., cognitive, emotional and practical) for using digital devices (Eshet-Alkali & Amichai-Hamburger, 2004). Teachers' use of such devices might differ from the use of the devices in other professions, as the use requires adequate pedagogic-didactic evaluation and an awareness of its implications for learning (e.g., Røkenes & Krumsvik, 2014).Tømte (2013) found that the use of digital devices as part of a discipline makes up part of teaching practice at teacher education institutions. Teachers

are embedded in a professional context at their own school and in the municipality, where teacher professional development is provided. At the same time, they use digital and analogue devices in their private lives, where they might have developed individual preferences. As teachers in general have a certain professional freedom, their individual preferences for such devices in their private lives might affect how they use analogue and digital devices in class (e.g., Goodson, 2014).

In sum, the three theoretical perspectives comprising socio-cultural theory, assumptions on differences in subject epistemology and teacher professional development, were used as a framework when analysing the data.

Method

Context
Our case is one lower secondary school, with approximately 350 students and 40 teachers, located in a middle-class municipality near Oslo, in Norway. School leader and teachers provided a positive attitude toward the one-to-one implementation that was initiated and followed up by the municipality, where students at all primary and lower secondary schools received their own Chromebook. This looks like a portable computer, but it has a touch-based screen. The implementation included strategies for teachers' professional development, such as ICT network groups within and across schools. All schools had local ICT supervisors, appointed from local teachers at each school. Therefore, they had similar strategies for implementation of the digital devices. The technical aspects of the implementation were mainly successful, with very few first order barrier issues (Tømte et al., 2019).

Data collection
Building on a larger evaluation study (Tømte et al., 2019), this article draws on longitudinal data collected at one lower secondary school, at three points of time: 2017, 2018 and 2019. Data were collected by classroom observations and interviews with a purposive sample of teachers in mathematics and Norwegian in grades 8, 9 and 10. In the evaluation study, in total 29 teachers were interviewed, 15 in Norwegian and 14 in mathematics, and 28 classroom observations were conducted.

Teachers in our sub-sample were strategically selected from the overall study. They represented different age groups, genders and years of profession, and we could follow them over the course of, maximum, three years. This article draws on interview data from six teachers (three in mathematics; three in Norwegian) and classrooms observations from their teaching. The sample consisted of four female teachers and two male. Two teachers had been a relatively long time in their profession, while the remaining teachers were either relatively newly beginning teachers, or teachers with some years of experience.

Furthermore, they represent different cases on the continuum of 'analogue to digital' preferences and use of devices. Two teachers could be described as mostly analogue oriented and two as mostly digital oriented; the remaining two teachers appeared to be balanced in their use of digital and analogue devices. Teacher interviews lasted about approximately one hour, while classroom observations were scheduled for one lesson, that is, 45 minutes. In sum, our data represent various profiles of teachers in both subjects providing a good point of departure for our analysis.

Instruments

We have used semi-structured teacher interview guides and observations.

The teacher interview guide included the following questions: 1) How do you use Chromebook? 2) How do you use Chromebook in class? 3) What is your perception of having one digital device for each pupil? 4) What are your experiences of the new technology?

Observation guide: the observation guide included a protocol for data collection including a standardized guideline, information about the name of the observing researcher, date and time, and ethical standards. The protocol also captured context information, for example on the subject and number of students. With respect to this article, the guide collected the following information: 1) Aim of lesson; 2) Digital and analogue device used in the lesson; and 3) Communication between teacher and students.

Analysis

Our approach in constructing cases of teacher perspectives was informed by thematic analysis for identifying, mapping and analysing patterns in the data, at a maximum of three time points, in order to explore changes. This implies an analysis of the transcribed material and our notes from classroom observations, by grouping and coding raw text in relevant categories, combining an inductive and deductive strategy (Braun & Clarke, 2006). By adding notes from observations to teacher interviews, we combined two different perspectives to validate our findings. Further, the analyses were validated by all authors. The first author conducted a pre-coding of the material and its results were discussed with all co-authors.

Findings

We present the perspective of teachers in Norwegians and mathematics, who differ in how they balance analogue and digital devices in their attitudes. We labelled these perspectives: positively evaluating analogue devices (analogue oriented), critically reflecting both devices (balanced), and positive evaluating digital devices (digital oriented).

Teachers in Norwegian

In the following, we describe three teachers' perspectives in Norwegian according to their combination of analogue and digital devices.

Analogue oriented: 'to keep handwriting is important'

We perceived this teacher as open-minded and enthusiastic; in class she provides a perspective, where analogue and digital devices are equally applied. She mentions her membership in a network, helping colleagues in how to use digital devices. For this teacher we collected data in 2017, 2018 and 2019.

Addressing the relation between using digital and analogue devices, she stresses the importance of choosing digital devices with 'a clear purpose'. At the same time, she refers to the continuous use of analogue devices like the blackboard, for example, when she started discussing a new topic with students by using mind maps. She highlights being better connected to her students when using blackboard instead of a digital device. This teacher also shows an attitude towards handwriting and analogue devices to continue to be important for future learning. She refers to students still preferring handwriting, which might be related to a rule she introduced, requiring handwriting until grade 9:

> [Students] are not allowed to take notes on the screen, while I am writing on the board, because I think to keep handwriting is important. This has worked very well, even if it has been challenging. (2018)

This quote indicates a certain authority. For her, both kind of devices appear to be important for developing teaching strategies; in the following, she stresses the advantage of spontaneity when using analogue devices:

> The blackboard is very nice because it makes it easier to be spontaneous. And making posters – the process of copying and thinking is different from that of being digital … students interact in a different way, compared to when they use the screen. (2019)

Moreover, this teacher refers to higher education when arguing in favour of a varied use of devices:

> At the university, there are still written exams on paper, which legitimates the importance of using both … screen and paper. At the same time, they should become more digitally[competent]. (2017)

This teacher says it is simple to switch between digital and analogue devices by closing the computer screen. Additionally, she refers to the perception of 'losing her students' behind the screen, indicating her worry of losing control.

Notes from classroom observations (2018-19) support this perspective of a purposeful, competent and varied use of learning devices. During the first part of the lesson, she uses analogue devices and traditional methods like newspaper articles, reading aloud and dialogue, switching to Chromebook in the second part. In the lesson observed in 2018, this teacher used Chromebook in various ways, by introducing several digital artefacts (e.g., Google Docs and Google Classroom), providing probable alternatives to students on how they could create digital collaborative texts. She also introduced a packet of biscuits, for helping students to activate their senses, such as the taste, smell, texture and sound of it, in order to stimulate them to write a descriptive text in collaboration.. The way this teacher used dialogue to guide the lesson with a varied use of artefacts proved to be meaningful in creating a diverse learning environment. At the same time, this example shows the importance of leadership, especially when using digital devices, not necessarily having an intrusive role in class. To acquire learning strategies becomes important, and this empathizes her point on how to combine analogue and digital artefacts.

In 2019, this teacher compares an earlier period when students had to take handwritten notes when they were free to use Chromebooks. She reflects over her own inability to know when students are ready with their digital notes, as they might escape into a game on-screen. For her its use has an impact on students' concentration, but she acknowledges that this generation is used to a rapid flow of actions, compressed information and new things continually happening. As she says: 'It's just what society has become.'

In general, data reveal a purposeful perspective. This teacher highlights the importance of a good combination, even stressing that digital devices have become important in education. From her point, digital devices will never catch all attention; they are 'just a tool' and 'do not necessarily make things better'. The point is rather 'how to use them'.

Balanced: 'I do not think it is the technology the students are enthusiastic about [...] it is rather the exciting story'.

We perceived this teacher as less enthusiastic with respect to the school's digital strategy, but as competent and supportive. For this teacher, we collected data in 2018 and 2019. Being relatively balanced in his narrative, he highlights the importance of a good story compared to new technologies:

> I do not think it is the technology students are enthusiastic about; … it is rather the exciting story – the narrative. … Thus, I try to make my lesson exciting. Of course. you can use the Chromebook to make the lesson exciting. (2019)

Our interview data reveal a reluctant perspective towards using digital devices. Here, this teacher positively comments on a school day without an Internet connection:

> That day was a funny day. … and we made the best of it. We should have more of those days. … I perceive that we use time very efficiently on days without an Internet connection. (2018)

In this quote, the teacher might also refer to the freedom in teaching before the one-to-one implementation. Later, he refers to his own 'balanced' approach using the Chromebook. When asked how he usually uses the Chromebook in class, this teacher refers to the device as a kind of notebook: 'This is what I am using it most for.' Comparing Chromebook for notetaking to the traditional notebook, he argues that the two modes, analogue and digital, are relatively similar, 'at least to a certain degree'. Further, he gives the impression that he prefers writing on the blackboard, even while referring to the Chromebook:

> I still draw and write much on the blackboard, but the Chromebook is nice to use to explain something that students can connect with pictures. Then they memorize better and understand better …. When they see a picture, they can relate it to knowledge. … Then I compose sequences of pictures and tell a story around it. (2018)

The two lessons we observed can be described as different. In 2018, the teacher combined digital and analogue devices in a concerted manner. In the second lesson, in 2019, he used exclusively printed books. The lesson in 2019 can be characterized as traditional, with paper reading material, individual reading and dialogue between teacher and students, while that of 2018 revealed a mixed picture in combining analogue and digital devices in a highly professional manner. These observations alone cannot reveal a real change over time, from choosing analogue to more digital methods. However, during the interview this teacher points out that he has developed over time in using the Chromebook, together with his class. For his students, the most difficult aspect of the work was finding and managing digital documents. This was commented on by the teacher: 'Finding and managing digital documents was an issue at the beginning, but keeping track of documents is still an issue for students, and might improve over time, maybe.'

This statement, when compared with our observations, indicates that changes over time are difficult to identify, and that these seem to be rather minor.

Digital oriented: '...it is fantastic to have such easy access to a device'

The third perspective is characterized by stressing the importance of digital competency and use of digital devices. For this teacher, we collected data in 2017 and 2018. She appears to

have used digital devices for a long time: 'As a teacher in Norwegian all work and writing has been in a digital mode for years' (2018). She refers to Chromebook mainly as a tool for text production, followed by its use for the creation of presentations and increasing possibilities, for example for assessment, sharing documents and collaborative writing. Her narrative as a 'digital teacher' might also be related to her role in the ICT network at her school.

The class observation reveals the impression of a well-organized teacher and competent class manager. During the interview in 2018 she points to routines when using Chromebook: 'I ask them to close it down very often; they should have it closed down when the lesson starts.' Such routines become further evident during an observation in 2018, where the teacher discusses a film with her students, switching between traditional conversations with students and between students and using devices such as Chromebook, the smartboard and the learning platform.

She also suggests the possibility of using Word in an analogue mode, which means the possibility of typing offline, and she reports that her students have not written by hand for a long time; she does not critically reflect on this issue, when compared with her colleagues' perspectives, a perspective which combines the use of digital and analogue devices.

Teachers in mathematics

In the following, we describe three teachers' perspectives in mathematics according to their combination of analogue and digital devices in class.

Analogue-oriented teacher

This perspective reveals an experienced user of digital devices reflected in his role as a former ICT supervisor. Despite his history in using digital devices and showing a positive attitude to the implementation of Chromebook, this teacher reveals an analogue-friendly perspective:

> Research shows that pupils learn more when taking notes by hand … this is the reason why I tell them to take notes by hand … if taking notes digitally, the brain does not work in the same way .., they learn less in-depth. This is my point. (2019)

The impression of a purposeful use of different devices is supported by our observations, where this teacher combines analogue and digital devices. At the same time, he reflects a positive attitude towards the use of digital devices: 'It is obvious. The PC is a fantastic tool.' One of his core points is that engagement matters, and not the device as such:

> … engagement is the point, not the device. … We have to create motivation to learn in another way. … irrespective of which tool we use, it is engagement that creates learning, not the tools… (2019)

Even though this teacher refers to having used digital devices for a long time, classroom observations reveal the impression of a rather traditional lesson, where the Chromebook is rather used in a static and 'analogue' instruction mode. A weakness of the data from this teacher is its limitation to 2019, and thus, allows no statements of change over time.

Balanced

Another teacher, female and in her 30s, reveals a perspective in combining analogue and digital devices and a reflective attitude. We collected data for 2018 and 2019. Classroom observations revealed a broad range of analogue devices, such as calculator, paper book, pen,

notebook and blackboard in addition to Chromebook. However, she prefers to use Chromebook in an offline mode.

Her perspective, however, reveals changes in ways to combine analogue and digital devices. She refers to years before the one-to-one implementation, when she had to book a set of computers beforehand and thus, felt a compulsion to work in a digital mode during the whole lesson. Mentioning the one-to-one implementation, she appears to have gained more professional freedom in choosing and combining different devices, illustrated by the following quote: '[N]ow, we can use digital devices when it is purposeful. It is easier now to use them for shorter periods.' The following statement from the interview in 2019 indicates an increased consciousness in using different devices:

> Over time, I might have become more conscious in terms of situations when it is most appropriate to use digital devices and when it is most appropriate to use handwriting.

For future use this teacher argues for a combination, referring to the importance of analogue devices for parts of her subjects: 'In mathematics … writing and the analogue is still important, also when working with geometry' (2019). When asked about her attitude towards the relation between analogue and digital devices, she takes a balanced perspective stressing learning benefits of handwriting and a 'connection to learning, from the eye to the hand'. Even though reflecting over the importance analogue devices for learning, at the same time she appears to downplay their importance for the future, illustrated by the following quote: 'Fewer and fewer professions require handwriting. In the future it is the PC they will encounter.' (2019)

Digital oriented: 'I am very happy to use digital devices.'
A third teacher, female and in her 30s, reveals a relatively digital-oriented perspective. We collected data for 2017 and 2018. This teacher reports that she has been involved in the implementation process and refers to progress, and that she has been a member of the project team at school and municipality level.

She shows a positive attitude towards digital devices and their use right from the beginning, stressing their advantages, downplaying the role of analogue devices. At the same time, she describes some lessons being more digital than others, stressing that the relationship between digital and analogue devices varies a lot over time (2017). In 2018, she mentions the possibility of working more effectively with the one-to-one solution, for example, by providing more variation in instruction and homework.

> There are many advantages … Providing and monitoring homework goes faster, there are more possibilities for variation in lessons in a more effective way, we can more easily switch from one task to another … there are many good digital materials […]. (2018)

Besides, this teacher mentions bad class leadership as the only disadvantage for using digital devices. In such a case, 'students might figure out how to do quite different things' (2018). She argues that digital devices should be a 'natural part of normal instruction … not the substitute for something else, but to do things more easily, more effectively.'

Additionally, she problematizes the case that handwriting is still taught in school, but no longer used much in everyday life. 'We no longer use handwriting, but we learn it at school. There are very few people writing letters at home …' (2018). In contrast to her analogue-oriented colleague and her colleagues teaching Norwegian, this teacher's perspective

is mostly positive towards the use of digital devices, illustrated by the following quotation: '[T]he future will be more digital and we will use more digital devices, both in private and professional contexts' (2018).

Discussion

We studied how teachers in one lower secondary school perceived using different devices in mathematics and Norwegian, and how these patterns changed over time. In the following, we will discuss the main findings through the lens of the three theoretical perspectives that inform our study.

Drawing on the socio-cultural perspective, we explored how teachers use and combine different artefacts and express themselves when explaining their use. Digital and analogue artefacts are perceived as 'useful in combination'. Teachers in mathematics appear to have a somewhat stronger preference for analogue artefacts, such as blackboard and books, and corresponding teacher-centred teaching methods. Further, findings illustrate that digital and analogue artefacts are perceived as complementary, being creatively combined by the most professional teachers. Nuances in teacher's perspectives, their reflections about variations reflect individual preferences in media use. Digital and analogue artefacts have each a different impact on learning. While learning by reading a book in a linear way has previously focused on memorizing, the emphasis in the 21st century seems to be rather on how humans create knowledge from information. Chromebooks might support learning, but differently than analogue artefacts. How teaching, learning and technology is understood has an impact on the organization of learning situations. Teachers' reflections are therefore crucial for questions of how and which specific learning artefacts are used, and for what purpose (Säljö & Moen, 2001).

Informed by a socio-cultural perspective, we interviewed single teachers in Norwegian and mathematics, and did not interview individual students on their perception of the teacher. This means that our analyses are restricted to the teacher perspective, excluding the student perspective.

Second, we assumed that that subject epistemology has implications for a teacher's choice of learning devices. In general, teachers appear to be relatively conscious in how they use learning devices in class. Having a long history in using digital devices does not necessarily go along with a one-sided positive attitude for these. One teacher in mathematics reflects on advantages and disadvantages of digital devices, stressing the importance of student engagement. At the same time, he is the exception when referring to evidence in favour of handwriting. Similarly, a teacher in Norwegian, stresses the importance of a 'capturing story', downplaying the impact of the digital device. Another teacher in Norwegian, however, enthusiastically refers to advantages of both types of devices; her point is that it is the *purpose* that matters for choosing a device. While the first two perspectives stress the content ('story') and the importance of student engagement, the last one stresses the importance of *purposeful use* and *choice* of the device. Teachers with a balanced perspective do not seem to prefer one kind of device; they appear to integrate both in a purposeful way, influenced by their preferences and socialization. Thus, they seem to have overcome 'first' *and* 'second order barriers', that is, resistance in adopting digital devices and combining them in a creative way with analogue ones, indicating 'second order change'. Teachers with a less balanced approach reflected less on *how* they utilize digital devices. Digital devices were used in a rather traditional way, such as reading on a screen (online) instead of reading on paper (offline). The pattern of these teachers indicates just 'first order change'; they do the same activities using

a new technology. Two teachers with a digital-oriented perspective seem to lack some more profound experience in teaching over time. Besides, our data show that the younger teachers might have a less sceptical attitude towards digital devices, indicating an age gap. Research has shown that teacher education in Norway provides students with limited knowledge in teaching with digital devices, whereas for years, large efforts have been made to raise awareness and skills for in-service teachers on that matter (Tømte, 2013). In sum, findings reveal that the purpose for choosing a device matters, along with pedagogical beliefs and individual preferences.

Teachers in Norwegian seem to acknowledge the possibility of using the Chromebook for different writing tasks and searching for information, while at the same time appreciating advantages of handwriting and paper books (see also Igland, Skaftung & Husebø, 2019). For mathematics, the teacher with the longest experience in ICT refers to evidence on the advantages of handwriting for learning. Thus, teachers in Norwegian might, to a greater degree, take on a socio-cultural perspective (Säljö & Moen, 2001; Vygotsky, 1978), choosing more student-centred strategies, for example by using artefacts such as student presentations or multi-modal texts, while those in mathematics to a greater degree might support a cognitive-psychological (Graham & Harris, 2006), teacher-oriented learning perspective, using artefacts such as a blackboard and workbooks. (see also: Siddiq, Scherer, & Tondeur, 2016). Teachers in this study still reveal an identity characterized by high autonomy and varied preference for teaching devices. Similar to teachers with a balanced perspective, McCulloch, Hollebrands, Lee, Harrison, and Mutlu (2018) found among young teachers of mathematics at secondary level in the US that many used technology only when they felt it was appropriate for a given topic, in alignment with their instructional goals.

Finally, we explored how teachers' use of learning devices is framed by their own socialization and individual preferences and opportunities for professional development. Teachers appear to vary in their enthusiasm about using new devices. Digital-oriented teachers appear to have a more positive attitude to digital devices; they might refer to their role as an ICT supervisor and be younger than those who seem to be more reluctant. However, teachers who have been using Chromebook in class for a long time might not have integrated it in an adequate pedagogic-didactic way, in accordance with the subject. Our data provide some teacher reflections about changing consciousness over time in using Chromebook, and in combination with analogue devices. At the same time, it is difficult to draw conclusions about change over time, as our study was conducted at only three points in time.

Concluding remarks

Our study identified reflective teachers, who refer to purposeful use of digital and analogue devices, with some variation. However, despite our findings showing similarities on a structural level, they show differences for the two subjects, with mathematics teachers applying a more analogue user pattern (see also: Egeberg, Hultin, & Berge, 2016).

How individual teachers combine different types of artefacts for achieving variation, and which type dominates, might also depend on the teaching situation and teacher characteristics. Combining data on teacher perspectives and use of devices, we get a more valid picture of the actual phenomenon of how analogue and digital devices are used by teachers in mathematics and Norwegian. We find indications of first-order changes for teachers in mathematics and less experienced teachers, and of second-order changes for teachers in Norwegian and more experienced teachers; this is a strength of our study.

Limitations and implications

Limited to the context to one school, we cannot generalize our findings to a larger teacher population at lower secondary school level. Thus, our findings represent illustrative examples of teachers in Norwegian and mathematics that combine the use of analogue and digital devices in a various way at different point in time. Additionally, informed by a socio-cultural perspective, we interviewed teachers in Norwegian and mathematics and did not interview individual students on their perception of the teacher. This means that our analyses are limited to the teacher perspective.

Additional research could investigate how students with different backgrounds (e.g., age, gender) perceive learning with analogue and digital devices, and how their experience might differ from that of their teachers. Teachers revealed different views of learning, as something purposeful, useful and efficient with respect to the future, related to extrinsic motivation (Ryan & Deci, 2000). Further research might investigate connections between teachers' views of learning and ways of using analogue and digital devices. Finally, our study is embedded in a country context, characterized as 'early adopting'. Further studies might replicate it in a different context, for example, in a country described as an 'early or late majority' in implementing new devices for learning in school.

References

Becher, T., & Trowler, P. (1989). *Academic Tribes and Territories*. Buckingham, Society for Research into Higher Education Open University Press.

Beckman, K., Bennett, S., & Lockyer, L. (2014). Understanding students' use and value of technology for learning. *Learning, Media and Technology, 39*(3), 346-367. https://doi.org/10.1080/17439884.2013.878353

Blömeke, S., & Olsen, R. V. (2019). Consistency of results regarding teacher effects across subjects, school levels, outcomes and countries. *Teaching and Teacher Education, 77*, 170-182. https://doi.org/10.1016/j.tate.2018.09.018

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology., 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Doron, E., & Spektor-Levy, O. (2018). Transformations in Teachers' Views in One-to-One Classes – Longitudinal Case Studies. *Technology, Knowledge and Learning*, 1-24. https://doi.org/10.1007/s10758-017-9349-5

Egeberg, G., Hultin, H., & Berge, O. (2016). *Monitor skole 2016. Skolens digitale tilstand*. Oslo.

Elstad, E. (Ed.) (2016b). *Educational Technology and Polycontextual Bridging*. Sense.

Eshet-Alkali, Y., & Amichai-Hamburger. (2004). Experiements in digital literacy. *Cyberpsychology and Behavior, 7*, 421-429. https://doi.org/10.1089/cpb.2004.7.421

Genlott, A. A., Grönlund, Å., & Viberg, O. (2019). Disseminating digital innovation in school – leading second-order educational change. *Education and Information Technologies*. 24, 3021-3039. https://doi.org/10.1007/s10639-019-09908-0

Gilje, Ø., Ingulfsen, L., Dolonen, J. A., Furberg, A., Rasmussen, I., Kluge, A., … Skarpaas, K. G. (2016). *Med ARK&APP. Bruk av læremidler og ressurser for læring på tvers av arbeidsformer.* [With ARK & APP]. Universitet i Oslo.

Goodson, I. (2014). Investigating the life and work of teachers. *Eesti Haridusteaduste Ajakiri, 2*(2), 28-47. https://doi.org/10.12697/eha.2014.2.2.02b

Graham, S., & Harris, K. R. (2006). Strategy instruction and the teaching of writing. A meta-analysis. In C. A. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (pp. 187-207). The Guilford Press.

Igland, M.-A., Skaftun, A., & Husebø, D. (Eds.). (2019). *Ny hverdag? Literacy-praksiser i digitaliserte klasserom på ungdomstrinnet.* [New everyday life?] Universitetsforlaget.

Islam, M. S., & Gronlund, A. (2016). An international literature review of 1:1 computing in schools. *Journal of Educational Change, 17*(2), 191-222. https://doi.org/10.1007/s10833-016-9271-y

Mangen, A. (2018). Mods of writing in a digital age: The good, the bad and the unknown. *First Monday, 23*(10). https://doi.org/10.5210/fm.v23i10.9419

McCulloch, A. W., Hollebrands, K., Lee, H., Harrison, T., & Mutlu, A. (2018). Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Computers & Education, 123*, 26-40. https://doi.org/10.1016/j.compedu.2018.04.008

Mercer, N., & Hodgkinson, S. (Eds.). (2008). *Exploring Talk in School: Inspired by the Work of Douglas Barnes.* Sage.

Mercer, N., & Littleton, K. (2007). *Dialogue and the Development of Children's Thinking. A Sociocultural Approach.* Routledge.

Olofsson, A. D., Lindberg, J. O., Fransson, G., & Hauge, T. E. (2015). Uptake and Use of Digital Technologies in Primary and Secondary Schools – a Thematic Review of Research. *Nordic Journal of Digital Literacy, 10*, 103-121 https://doi.org/10.18261/ISSN1891-943X-2015-Jubileumsnummer-08

Postholm, M. B. (2012). Teachers' professional development: a theoretical review. *Educational Research, 43*(4), 405-429. https://doi.org/10.1080/00131881.2012.734725

Rienties, B., Brouwer, N., & Lygo-Baker, S. (2013). The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology. *Teaching and Teacher Education, 29*, 122-131. https://doi.org/10.1016/j.tate.2012.09.002

Rogers, E. (1995). *Diffusion of Innovations.* 4th edition. The Free Press.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology, 25*(1), 54-67. https://doi.org/10.1006/ceps.1999.1020

Røkenes, M. F., & Krumsvik, R.J. (2014). Development of Student Teachers' Digital Competence in Teacher Education – a literature review. *Nordic Journal of Digital Literacy, 4*(9), 250-280. https://doi.org/10.18261/ISSN1891-943X-2014-04-03

Siddiq, F., Scherer, R., & Tondeur, J. (2016). Teachers' emphasis on developing students' digital information and communication skills (TEDDICS): A new construct in 21st century education. *Computers & Education, 92-93*, 1-14. https://doi.org/10.1016/j.compedu.2015.10.006

Säljö, R., & Moen, S. (2001). *Læring i praksis: et sosiokulturelt perspektiv.* Cappelen akademisk.

Tømte, C., Wollscheid, S., Bugge, M., & Vennerød-Diesen, F. F. (2019). Digital læring i askerskolen. Sluttrapport fra følgeforskning. NIFU-rapport 2019-27. NIFU

Tømte, C. E. (2013). Educating Teachers for the New Millennium? Nordic Journal of Digital Literacy, 8(1-02), 74-88. https://doi.org/10.18261/ISSN1891-943X-2015-Jubileumsnummer-10

Vygotsky, L. S. (1978). *Mind in Society. The Development of Higher Psychological Processes* (Vol. Cambridge, Massachusetts): Harvard University Press.

Wegerif, R. (2007). *Dialogic Education and Technology: Expanding the Space of Learning.* Springer.

Wertsch, J. V. (1991). *Voices of mind: A sociocultural approach to mediated action.* Harvard University Press.

Åkerfeldt, A. (2014). Re-shaping of writing in the digital age. *Nordic Journal of Digital Literacy, 9*(3), 172-193. https://doi.org/10.18261/issn1891-943x-2014-03-02