Nordic Journal of Digital Literacy

03-2013, VOL. 8

Editorial
Morten Søby
Learning to Be: Developing and Understanding Digital Competence
Page 134-138

Articles
Emma Petersson, Annika Lantz Andersson & Roger Säljö
Exploring Nature through Virtual Experimentation
Page 139-156

Agnese Karaseva, Pille Pruulmann-Vengerfeldt & Andra Siibak
Comparison of Different Subject Cultures and Pedagogical Use of ICTs in Estonian Schools
Page 157-171

Martin Carlsen
Mathematical Learning Opportunities in Kindergarten through the Use of Digital Tools: Affordances and Constraints
Page 171-185
Traditionally, the word literacy referred to the level of reading and writing skills needed for minimum functioning in a modern society. Translating literacy into other languages has proven problematic. ‘Literacy’ in English is associated with the cognitive realm and rarely directly conveys the intended conception of meeting complex demands through mobilizing a range of mental prerequisites. Several international studies note that talking in terms of skills provides only a narrow perspective on education and learning activities (OECD, 2002).

The OECD invited its member countries to participate in a four-year project: DeSeCo – Definition and Selection of Competencies (OECD, 2002), which originated in increasing international interest in outcome and the effect of training and education, as well as a need for a common frame of reference for identifying and analysing so-called basic components. Competence is defined here as: “[…] the ability to meet demands or carry out a task successfully, and consists of both cognitive and non-cognitive dimensions” (OECD, 2002).

DeSeCo focuses on three basic competency categories: (1) using tools interactively (e.g., language, technology), (2) interacting in heterogeneous groups and (3) acting autonomously. These competencies are important in different life situations and are defined as necessary to all of them. The DeSeCo report emphasises that basic components must be selected and defined in accordance with what societies and individuals within particular societal groups and institutions value. The DeSeCo report has become the foundation for international collaboration on work related to the concept of competence.

The use of the concept of competence in connection with primary and secondary education is relatively new. The concept of competence has been applied to adults’ knowledge and skills. With regard to lifelong learning, a comprehensive concept of competence has become an important term in educational policy, planning and quality studies.

The OECD emphasises that building competence concerns the whole person. It is about relating proactively to challenges posed by the environment and times in which we live along with meeting highly complex demands. Mere knowledge and skills are not sufficient in themselves. Strategies, attitudes and procedures are also required. Competence is a performance-related term describing a preparedness to take action: Competence is the ability and readiness to meet a challenge through action, when it is often implicit that the challenge is not a given, but depends on context; that it is not a routine challenge, but novel and not judged by given criteria for success, but by the outcome; whose form is not known in advance (Hermann, 2005).
In the Key Competences Recommendation, ‘competence’ is defined as a combination of knowledge, skills and attitudes appropriate to the context (European Parliament and the Council, 2006). The recommendation of the European Parliament and the Council (2006) recognized eight key competences for lifelong learning: communication in the mother tongue; communication in foreign languages; mathematical competence and basic competences in science and technology; digital competence; learning to learn; social and civic competences; entrepreneurship; and cultural awareness and expression.

Digital competence is defined in the Recommendation as involving the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. Digital competence has been confirmed as a relevant priority for the Commission in more recent policies, actions, and communications (European Commission, 2010a, 2010b).

The report Digital Competence in Practice: An Analysis of Frameworks (Ferrari, 2012) analyses 15 frameworks that develop digital competence. These frameworks vary in scope (from school curricula to certification schemes to academic papers) and target groups (adults, children, the young, the elderly). The analysis carried out in this DIGCOMP report identified three areas to be reported upon: a definition of digital competence, the identification of competence areas and a discussion about the levels. According to the different understandings of digital competences in the cases studied, Ferrari (2012) proposes the following definition of digital competence:

*Digital Competence is the set of knowledge, skills, attitudes (thus including abilities, strategies, values and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, socialising, consuming, and empowerment.* (Ferrari, 2012)

This definition is encompassing and should be considered for the development and implementation of digital competence frameworks. The DIGCOMP report highlights that digital competence is built on different learning domains (knowledge, attitudes and skills) and spreads across several competence areas. Several of the frameworks selected for the analysis in the report suggest that technical skills constitute a central component of digital competence. Having technical skills at the core of a digital competence model does not give enough importance to other equally relevant aspects. Digital competence should be understood, in its wider sense, as a multi-faceted concept.

The new report A Framework for Developing and Understanding Digital Competence in Europe (Ferrari, 2013) presents the final findings of the DIGCOMP projects and proposes a framework for digital competence for all citizens. The output of this project was based on a data collection phase (including a literature review, case study analysis, and an online survey) and an intensive stakeholder consultation (including workshops, interviews, reviews by experts, presentations at seminars and conferences. The areas of digital competence are the following:

1. **Information:** identify, locate, retrieve, store, organise and analyse digital information, judging its relevance and purpose.
2. **Communication:** communicate in digital environments, share resources through online tools, link with others and collaborate through digital tools, interact with and participate in communities and networks, cross-cultural awareness.

3. **Content-creation:** Create and edit new content (from word processing to images and video); integrate and re-elaborate previous knowledge and content; produce creative expressions, media outputs and programming; deal with and apply intellectual property rights and licences.

4. **Safety:** personal protection, data protection, digital identity protection, security measures, safe and sustainable use.

5. **Problem-solving:** identify digital needs and resources, make informed decisions as to which are the most appropriate digital tools according to the purpose or need, solve conceptual problems through digital means, creatively use technologies, solve technical problems.

The OECD’s view of competence influences policy and education: Digital competence has set the agenda for innovation, education and pedagogy in Europe. Digital competence is a multimodal and complex concept, constantly changing with the development of digital media. Media development is multidisciplinary by its very nature. Over the last 15 years, digital competence has established itself as a key concept in educational policy and in educational research.

Digital competence can be seen as a concept whose status is “essentially contested” (Connolly, 1993). It has a conceptual core or essence that is subject to discussion on a fundamental level. Much in the same way as with the word ‘democracy’, several participants will join discussions and efforts to define the concept of digital competence. A discussion on digital competence may take place along three dimensions. Firstly, it is about appraisal or values. Secondly, there is a complex span between skills and knowledge and formative education. Thirdly, there is an openness that creates potential for several possible interpretations and areas of use.

The concept has had a double function as an agenda setter. On the one hand, it is the principal political concept in innovation policy and in educational reform. On the other hand the concept has become an objective in the development of schools and in practical pedagogy. Educationalists are now working on anchoring digital competence in theories for learning and media development and further developing the concept. The term digital competence has been something akin to a password into new fields politically as well as pedagogically.

*Digital competence* is more important in the information society than focusing solely on skill-based activities. Digital competence expresses an overall understanding of how children and young people learn to develop their identity and learning strategies. The term will also encompass and combine the application of skills, qualifications and knowledge. In this way, digital competence points to an integrated and comprehensive approach that enables us to reflect on the influence of ICT on different qualifications such as communication skills, social skills and pupils’ critical judgements. By focussing on a greater degree of the use of ICT integrated in all subjects, both teachers and pupils will develop the necessary ICT skills while building competence in areas such as navigation in and critical appraisal of sources, and an understanding of the social significance of digital technology.

The SMIL study presents results from one of the largest ICT studies, conducted in upper secondary schools in Norway among 17,529 students and 2,524 teachers. The background for the study is
based on the need to develop educational monitors and indicators for ICT-use. The SMIL study shows that the pedagogical use of ICT varies substantially between different groups of students, groups of teachers, professional groups and educational programs.

Some of these differences are related to the characteristics of different subjects, the lack of appropriate digital tools in different subjects, as well as lack of digital competence. For this reason, one of the most important implications of the findings of the SMIL study is that an increase in digital competence among teachers is one of the most important means of increasing students’ learning outcome when ICT is used. (SMIL, 2013)

The study also shows that students need digitally competent teachers as role models for their professional ICT use. More specifically, they need teachers who have a salient leader role in the classroom, who possess a broad array of methods, and who follow them closely in their formative and individualized assessment.

Figures from the Norwegian Centre for ICT in Education Monitor (in press 2013) shows that eight out of ten upper secondary students (VG2) believe that the use of computer / tablet helps them understand the subjects better; it gives more desire to learn and makes it easier to learn school subjects.

The increasing ICT use in schools reflects the evolution of society, and the school provides both challenges and opportunities for learning. The SMIL study points to the relationship between a high grade point average from upper secondary and extracurricular low ICT use in high school, and that the teacher’s digital competence and screen time increases the ability of good classroom management and enhances learning with ICT.

Successfully preparing all learners with the skills and capacities for 21st century citizenship – global awareness, creativity, collaborative problem-solving, self-directed learning – is no small order, and many educational leaders are finding that the traditional forms of education that have evolved through the end of the last century are simply inadequate for achieving these goals. (Groff, 2013)

A fundamental reason to pursue digital media rich environments is that we live in a digital world. This raises many question, concerns, and unknowns that should matter to both policymakers and educators – all of them stemming from the fact that education has the responsibility to equip young people with the necessary digital competence that will allow them to cope with the challenges that connectedness is currently posing to them.

References


SMIL (2013): http://www.ks.no/PageFiles/41685/Sluttrapport_SMIL.pdf


---

1 In the Norwegian white paper St. m no. 30 (2003-2004) *Kultur for læring (A learning culture)* digital competence is defined as: “[…]the sum of individual ICT skills, such as reading, writing and maths, and more advanced skills ensuring a creative and critical use of digital tools and media”. ICT-skills include making use of software, searching, finding, processing and controlling information from various digital sources, while critical and creative ability also requires ability to evaluate information and sources, interpretation and analysis of digital genres and media types. Thus, digital competence can be regarded as a very complex form of competence (48).
Exploring Nature through Virtual Experimentation
– Picking up Concepts and Modes of Reasoning in Regular Classroom Practices

Emma Petersson, Annika Lantz Andersson & Roger Säljö

Abstract

In the present article, a study of the use of a virtual lab in environmental science teaching is reported. The lab was used as part of regular instruction; the idea was to provide a context to learn about experimentation as a research method. The study builds on a sample of 80 of 511 students, and uses pre- and post-test data of students’ insights about concepts and procedures relevant for designing an experiment in environmental science. The results show that students discovered some principles of how to organize an experiment. A majority of the students appropriated some of the relevant terminology and procedures relevant for organizing experiments. However, the findings also pointed to limitations in how students were able to reason about experimentation. A major problem for the students was to understand the role an experiment plays in resolving an issue. Such insights do not emerge from using the virtual lab per se, but rather from realizing the role an experiment plays as part of a scientific study of a problem.

Keywords: virtual experiments, science learning, science literacy
Introduction

The background of this study is an interest in two related issues. The first one concerns problems of how to organize learning in times of rapid changes in the knowledge base. The second issue concerns how digital tools – virtual labs – may support learning and understanding of basic modes of scientific reasoning in environmental science. The connection between the two issues can be found in the manners in which experimentation may be seen as a generative practice for producing knowledge. Recognizing what an experiment is, and how it is conducted, are keys to understanding critical principles for how to generate knowledge. Given the rapid development of digital media, it seems fruitful to ask if virtual experimentation may contribute to learning such generative skills. However, our interest is what can be achieved within normal educational practices. Thus, we are not focussing on testing sophisticated digital tools in contexts where there are media experts and other extra resources around, as is commonly the case in research on digital tools in classrooms (cf. Ludvigsen & Mørch, 2010). Rather, our interest is to scrutinize signs of learning in settings where a virtual lab is offered as an optional resource for students to use when learning about a specific environmental issue: ocean acidification.

Learning in knowledge intensive societies

At present there is an unprecedented expansion of human knowledge following large investments in science and research in most countries. Already a hundred years ago, John Dewey (1966) pointed to the problems of how to organize instruction so as to accommodate to the increasing production of knowledge. One of his reflections concerned the difficulties that this development posed for schools when preparing students for their future work and life in a democratic society undergoing rapid change. In 1916 he argued that “industry at the present time undergoes rapid and abrupt changes through the evolution of new inventions. New industries spring up, and old ones are revolutionized.” (1966, p. 119). As a consequence, “an attempt to train for too specific a mode of efficiency defeats its own purpose. When the occupation changes its methods, such individuals are left behind with even less ability to readjust themselves than if they had a less definite training” (loc. cit.). Thus, the increase in knowledge produced cannot be met by making education more specialized or by tailoring it too tightly to current conditions.

What Dewey observed about the difficulties of preparing young children for rapidly changing social conditions and technological shifts is a relevant premise for addressing contemporary issues in education as well. Metaphors such as the information or knowledge society have been invented to point to the dynamics characterizing “fast capitalism” (Gee, Hull, & Lankshear, 1996) in a globalized world where production of information has reached levels that were hard to imagine even a few decades ago. Immense numbers of scientific publications pour out findings, observations and claims that, in principle, would be relevant for education to take note of. New fields, such as in the areas of environmental science and the life sciences, emerge. But incorporating all these developments is not possible; education cannot continuously accommodate to new inputs at the pace at which they are currently produced; rather it has to exercise a high degree of selectivity and consider how to accommodate to new circumstances brought about by the intense knowledge production.

To deal with the problem of how to handle this situation of a rapidly increasing knowledge base, Dewey proposed that learning should take place through inquiry. Inquiry as a pedagogical concept has many sides to it, and it is a cornerstone of Dewey’s pragmatist approach to knowledge, learning and interaction with the world. The definition Dewey (1938, p. 108) provides is quite complex and
implies that inquiry “is the controlled or directed transformation of an Indeterminate situation” into
one that is comprehensible as a “unified whole.” Thus, inquiry is an “operation activated in response
to doubt” (Talisse, 2002, p. 76), which, in turn, generates an insight or solution of a problem. Inquiry,
accordingly, implies that the interaction with the environment is guided by a question, something
that the individual *qua* learner is wondering about; it is when we are in what Dewey refers to as an
indeterminate situation that we engage in inquiry in order to transform the problem encountered
into something that we can grasp and act on.

For Dewey inquiry is a characteristic of science as a human activity; science is the “conduct of inquiry
as inquiry” (Dewey & Bentley, 1949, p. 238), i.e. the continued search for indeterminate situations
that may be transformed into something that we understand. This makes science a model for how
learning can be organized. If students learn how scientists formulate questions and how they study
them, they will develop an insight into the nature of scientific knowledge and its character at a more
general level.

**Learning through virtual experimentation**

Experimentation is important in many fields of research. Learning about the logic of how
experiments are conducted therefore qualifies as a significant constituent in the development of
science literacy. Doing experiments involves understanding a particular language with mediating
terms and concepts such as sample, control group, variable and so on (Lemke, 1990). However,
appropriating such terms is not enough; a deeper insight into experimentation implies that one
learns how to organize such specific knowledge generating practices. One must be familiar with
how experiments may be designed in order to give valid answers to specific problems. Such
knowledge has conceptual, practical and performative elements, and the learner has to appropriate
a range of insights necessary for structuring empirical studies in expected manners (Ault & Dodick,
2010).

In recent years, a large number of resources for performing virtual experiments have been produced.
Virtual labs, in many areas and at all levels of education, are available online. Also, there is an intense
technical development, where major players in science, such as NASA, science museums,
universities and other institutions take active part. On the Internet, one can participate in activities
of performing experiments in various branches of physics, chemistry, life sciences and other
fields.

The research on the implementation of such resources for teaching has primarily focused on the
design of virtual tools (cf. Furberg, 2010). The basic aim of these studies is to test hypotheses relating
to the claim that virtual tools “offer the potential to improve learning” (Ramasundaram et al., 2005,
p. 22), since they familiarize students with working methods that resemble methodologies practised
by scientists. Thus, virtual tools “include learning from observation, developing hypotheses to
explain observations and testing of hypotheses with datasets” (ibid., p. 23). For instance,
Ramasundaram and colleagues (2005) developed an environmental virtual field laboratory (EVFL)
offering a complement to non-virtual fieldtrips. The idea behind EVFL is to mimic a traditional
fieldtrip through 3D animations, and focus questions and simulations, related to the environmental
properties of flatwood landscapes in Florida. The authors argue that EVFLs enhance learning by
offering instructional opportunities that are not available in non-virtual labs. Similar arguments are
presented by Heermann and Fuhrmann (2000), who argue that virtual labs have potentials for
improving learning and increasing student motivation. Claims made in the literature are that virtual tools are less time-consuming, more flexible, clean, rapid, cost-effective, safe, and that they open up for types of experimentation that otherwise might not be possible for students to engage in (Dalgaro et al., 2009; Shim et al., 2003; Zacharia, 2008). Using virtual tools in educational settings is believed to provide opportunities for inquiry learning and for the learning of scientifically relevant modes of working (Bell, T. et al., 2010; Shim et al., 2003). In a recent literature review on the uses of ICT in environmental education (EE), Fauville et al. (2013) conclude that the association of EE and ICT in the classroom challenges long-established teaching traditions and opens up for a wide range of instructional opportunities. Fauville et al. argue that there is a rich variety of digital tools and applications, but far less research on what such resources imply for student learning. It is argued that such tools make it possible to overcome budget, time and security issues by giving students possibilities to virtually conduct experiments that are otherwise not possible to run in schools (Fauville et al., 2013).

However, as is well known from attempts to introduce digital technologies in school, the world of teachers and students is very different from that of designers (e.g. Arnseth & Ludvigsen, 2006; Lantz-Andersson, Linderoth & Säljö, 2009). As argued by Krange and Ludvigsen (2009) “to improve students’ knowledge constructions, it is not enough – nor in principle possible – to perfect the design of the technology” (p. 268). Also in research, there is a focus on presenting new technologies, and making claims about their advantages, rather than studying the concrete use of them and the consequences for learning processes and outcomes. Only relatively few studies analyse how students reason when using a virtual laboratory environment and critically attend to the pros and cons (cf. Chen, 2010).

Following this line of reasoning, virtual experiments introduce new practices that imply a remediation in the Vygotskian sense (Wertsch, 2007; Vygotsky, 1978). Experiences are made in new manners, and the virtual context does not mimic the traditional hands-on experiment in the science lab. The virtual environment as part of school work must be understood in terms of its own set of affordances. Also, and as we have already alluded to, new technologies introduce their own problems when it comes to implementation in the classroom (Cuban, 1986).

The study

The present study is part of a project that seeks to explore how, and if, students profit from working with a virtual lab. The project also includes extensive video documentation of students while working with the virtual tool (to be reported on). The issue we address here concerns to what extent students appropriate the fundamentals of what doing experiments implies. The focus is on scrutinizing students’ written answers to identify how they formulate what characterizes an experiment and elaborate on how an experiment may be designed in order to provide information relevant for a problem. In other words, is it possible to identify signs of learning in students’ ways of picking up concepts and modes of reasoning relating to how to conduct experiments after engaging with a virtual lab?

The study has been carried out as a part of a bi-national collaboration between schools in the USA and Sweden on issues of climate change and habitat preservation. In this case study we have merely used empirical material from schools in the USA. The empirical material is naturalistic in the sense that the classroom activities did not include any interventions or participation from researchers, rather the classroom activities involving the virtual lab were part of a regular instructional setting.

© Universitetsforlaget, Nordic Journal of Digital Literacy, Vol 8, 2013, Nr 03

142
We would like to stress that in this particular study we do not have access to data about how students used the lab in the classroom situation; rather the analysis focuses on exploring possible outcomes. However, the strength of this material is that it contains documentation of learning outcomes of over 500 students working in a naturalistic instructional setting with a virtual lab. As far as we have found, there is no study in the literature with a similar dataset.

Setting and participants

The students worked on issues relating to ocean acidification and they had access to a virtual lab called Acid Ocean Virtual Lab (AOVL). The virtual lab was integrated into the regular classroom activities, and the teachers of each class organized the teaching as they saw fit. Four teachers and altogether 511 students (aged 12 to 18) participated in the study. The age distribution must be taken into account when interpreting the results. The research data were generated through a pre-test and a post-test given after a period of one to two weeks. In the post-test, 469 of the 511 students took part and the same questions were given again. In the weeks of lessons in-between the pre- and post-test of this study, the students worked independently during one lesson with the AOVL in the marine science teaching. The teachers did not cover any part of ocean acidification before the activity was presented, nor did they intervene in the students’ activities. Thus, the point of the present study is to see if any traces of learning through a digital tool may be seen in this environment, where the tool is offered as a resource for learning.

The analysis builds on a sample of 80 students. These students were randomly selected from the group that took part in both pre- and post-test. The selection was done in order to limit the burden of the analysis of the empirical material.

Acid Ocean Virtual Lab

In order to understand the logic of the study, a brief presentation of the AOVL is necessary. The AOVL is a virtual lab where students get an opportunity to study acidification of the ocean and its impact on the growth of sea urchin larvae. It consists of three parts that the students attend to and use: (a) information regarding basic facts about ocean acidification; (b) lab session, and (c) measurement exercise and information about the consequences of ocean acidification on marine organisms. The lab is designed to mimic a ‘real’ lab setting with equipment such as beakers, pipettes etc. (Figure 1).

In the virtual lab students perform activities such as setting up replicate cultures, feeding the larvae, making water changes, and observing the changes in growth of the sea urchin larvae over time. In the third part, the students measure the growth of samples of larvae from water with different pH levels and compare them. The outcome of the experiment is based on statistical data from authentic scientific research.
Problem to be solved by students

The assignment given to the students before and after their use of the virtual lab is a question that serves as a target of our analysis of the impact of the AOVL activity. The problem was formulated as follows:

You are an environmental scientist who is hired to complete an environmental impact report for a proposed project. Tropical Fisheries of Hawaii plans to open a fish hatchery on the Luau River, and the river opens to a bay with a large coral reef. Biologists are concerned that water discharge from the hatchery could impact the pH of the river and the bay. What sort of an experiment could you do to see if a change in pH might have an effect on the growth of the coral?

Apart from this particular task, all other questions in pre- and post-test are multiple-choice. The task thus implies suggesting an informative experiment that would provide relevant information about the consequences on the corals of a change in the pH in the river and the bay. The task is quite demanding and it should be noted that the students were required to do this in writing.

Analysis of data

The idea behind the study is to analyse to what extent students begin to appropriate (Rogoff, 1990, p. 193ff; Wertsch, 1998, p. 32ff) a language and modes of reasoning which emulate the ideas and practices of how to do experiments. The task is quite complicated, since it implies that students have some understanding of what an experiment is in a more precise sense. As Gyllenpalm, Wickman & Holmgren (2010) show, the term experiment is used in different ways in classrooms, and often
in a quite vague sense as referring to any manipulation of objects or as a synonym to trying and
testing something. Here the task is one of designing an experiment in the scientific sense.

The analysis thus has to be commensurate with the multidimensionality of the task and our analytical
interests. To analyse if, and in that case how, students’ reasoning changed between the two occasions,
the following data on the pre- and post-tests were attended to:

1. The use of scientific terms
2. The nature of the reasoning engaged in when responding to the question

We will now briefly explain these indicators.

A) Analysis of use of scientific terms

As we have already pointed out, learning how to carry out experiments implies appropriating a
certain terminology. A part of the analysis implied examining students’ use of experimentally relevant
terms, before and after their use of the AOVL. The keywords selected were:

PH
Acid/basic/neutral
Sample
Test/measure/examine/observe
Over time/before and after
Control group
Control
Environment
Compare

Each student’s use of the selected keywords in the pre- and post-tests was counted. One keyword
could appear more than once in an answer. The terms selected are considered central when it comes
to understanding the nature of the particular experiment to be designed by the students. For instance,
the terms pH, acid, basic and neutral are terms that are important in relation to the experiment that
the students are to outline, because the problem concerns water quality and a change in pH. Other
important and experimentally relevant terms are: sample, test, measure, examine, observe, over time, before
and after, control group, control, environment and compare. Also, the choice of these terms was dictated by
findings in previous research in the area of science literacy (e.g. Lemke, 1990) as well as by
scrutinizing the terminology used in the AOVL.
B) Analysis of student reasoning

The second level of our analysis concerns the manners in which students attempted to outline an experiment that could shed light on the problem of the possible impact of the fish hatchery on acidity and the growth of the coral. This is thus an issue of searching for signs of appropriation of a specific mode of reasoning that involves combining semiotic tools in a relevant manner. The analysis of the students’ answers resulted in a hierarchical description of learning outcomes that ranges from not providing any suggestion about how to proceed, to giving a functional account of how an experiment could address the issue. A five-level category system is empirically derived, meaning that the students’ answers on the pre- and post-test formed the basis for describing and delimiting the categories. The category system is designed to describe how students’ answers to the problem approximate a description of a relevant experiment. The five-level category system is as follows:

Category 1. Don’t know/no answer

Category 2. Suggests solution to the problems with the water (but does not describe a study)

Category 3. Suggests testing the water (or pH or corals)

Category 4. Suggests testing the effects of water status on corals

Category 5. Outlines study/experiment

As can be seen, categories 3, 4 and 5 imply that the students suggest some kind of investigation to deal with the problem given, while categories 1 and 2 do not outline any study at all (cf. Hakkarainen, 2004 and Bell, P. & Linn, 2000 on the use of category system for the analysis of student inquiry and argumentation in science education). The details will be presented in the next section.

Results

At a general level, the results yield evidence of an increasing familiarity with experimentation as a way of addressing an issue of the kind described in the problem. However, at the same time it is also obvious that the activities had quite varied implications for student reasoning.

Use of language of experimentation

The empirical material documents an increase in student uses of relevant distinctions in the context of doing experiments. More of the target terms were used on the post-test as is evident from Table 1.
Table 1. Use of keywords on pre- and post-test

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>68</td>
<td>88</td>
</tr>
<tr>
<td>Test/Measure/Examine/Obsnere</td>
<td>40</td>
<td>57</td>
</tr>
<tr>
<td>Sample</td>
<td>26</td>
<td>44</td>
</tr>
<tr>
<td>Over time/Before and after</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Acid/Basic/Neutral</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Control</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Compare</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Control group</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Environment</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>243</td>
</tr>
</tbody>
</table>

Terms students used most frequently on the post-test were pH, test, measure and sample. The word pH can be found in the formulation of the question, which might have induced students to use it frequently. For other, potentially relevant, distinctions, the differences between occasions are small. In statistical terms, the mean number of terms used between occasions increases significantly (from a mean of 2.2 to 3.0, z<.001, Wilcoxon signed ranks test).

Table 2 shows an example of how students, when answering the post-test, use their experience from the laboratory session so as to be able to extend their scientific language.

Table 2. Examples of use of experimentally relevant distinctions

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1 «I could take a sample of the water from the Luau River, and then test the small amount of water contacting the pH with the sample water and see what happens.» (Category 3)</td>
<td>«You could take samples from the water before they build the hatchery. Then you could take a sample of the water after they build the hatchery (the water it might be, but not literally after they build the hatchery). Take a pH test with both of these samples and compare the results. This will tell you how much more pH there is. Then, you think about how does pH affect the coral – for example, if there is more pH, then the coral will die/live. So with the samples’ results and and your reasoning/thinking, you can tell what will happen.» (Category 3)</td>
</tr>
</tbody>
</table>
Student reasoning

The most interesting aspect of the results is of course how the students managed to understand the logic of experimentation. The unit of analysis here, thus, is the reasoning they engaged in as they formulated their answers. The categories mentioned above are empirically derived and give an overview of the types of accounts that were given. The category system is hierarchical, i.e. the higher up in the system an answer is classified, the more elaborated it is, and the closer it approximates the design of a valid experiment.

Below the criteria for each category are described, and there are also a few empirical examples to illustrate prototypical answers.

Category 1. Don’t know/no answer

This category includes answers that give no indication about how to deal with the issue formulated in the question. Alternatively, the answer is just a one word reply which in no obvious way connects to the question.

«Do something» (Pre)
«I don’t know» (Post)

Category 2. Suggests solution to problem with water (but does not describe a study)

Answers in this category suggest a solution to the problem with the water, should the hatchery be built. The students, however, are not answering the question posed about what kind of experiment could be designed to investigate the possible effects of the hatchery. Instead, they predict what will happen if the hatchery is built.

«Try to move the hatchery to a place a little farther away from the water» (Post).

Category 3. Suggests testing the water (or pH or corals)

Answers in the third category imply that one should perform one or more tests to settle the issue: test of water, of pH or of corals. These suggestions about testing are given without any specification about what function the test would have in relation to the question. Answers including conceptions connected to pH, such as acid and basic are also placed in this category. Example of an answer is:

«Acidic test» (Post)

Category 4. Suggests testing the effects of water status on corals

Answers in the fourth category explicitly suggest testing the effects of water status on corals. This implies testing the growth of corals in different water conditions, for example in water with different pH levels.

«Extract coral samples from the river bay and put them in different pH solutions and see if the solutions affect the coral» (Pre)
Again there was a certain variation in how explicit the answers were when specifying how to carry out the experiment, and whether, for instance, the students explicitly used the term experiment in their account. But the important specification here is that students argue that the functional effects of water on corals should be examined.

**Category 5. Outlines study/experiment**

In the fifth category the answers describe/outline an empirical study/experiment. An example of such answers is:

«To observe the natural pH of the water, I would first gain a sample of that water and put it in six separate jars. I would then get a sample of water with a more acidic pH and also have that in six different jars. Then, I would take sample of the coral and put six samples in the natural pH of the water and then put six with a more acidic pH. I would let the coral sit in the water for a week so that the water could take affect on the coral. After this process, I would take the samples of coral and make six slides for them. I would put them under microscopes and note the size of each sample and note whether or not the more acidic pH had taken affect on the coral. With the six different samples of each, it would allow me to observe and make sure that the experiment was consistent rather than just chance of luck.» (Post)

These answers are thus more precise and specify how empirical observations in an experiment-like context could be made over time. The student texts may be more or less explicit, but the reasoning implies that an experiment which could provide insights into the effects of water acidity on corals is described. A less elaborate example is the following:

«An experiment that you could do is: get a few samples of coral. Put the coral in its normal environment with normal pH, put another coral in an acidic pH, and put a coral in a basic pH. Then observe to see how the coral grows and if it grows better or worse in which environment.» (Pre)

In this case, the participant argues that one should take «a few samples of coral» and put them in different environments. Then one should observe coral growth; thus, the argument is that one arranges a situation in which the environment is systematically varied in order to find out the effects on coral growth, which is treated as outcome measure.

**Learning in the context of a virtual lab**

The above results indicate the variation in responses to the problem posed among students. At a general level, the answers given on the second occasion are more elaborate and relevant, and include more of the expected terminology. A critical issue is of course if it is possible to connect the answers given on the second occasion to the experiences made while using the AOVL. However, the AOVL is the only activity of this kind that has taken place in the classroom.

The general shifts in the nature of the answers are presented in Figure 2. Of the 80 students in the sample, 35 gave answers that were classified in a higher category on the second occasion than on the pre-test. The most common shift is from Category 1 upwards.
Twenty students answered "I don’t know" (or similar) on the pre-test. Four of them did not change category position on the post-test. Consequently, 16 students changed category upwards. Table 3 exemplifies (cf. Table 2) how students come up with more elaborate answers on the post-test.

Table 3. Change of category

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 2</td>
<td>(No answer) (Category 1)</td>
</tr>
</tbody>
</table>

Seven students changed their category position to a category with a lower rank. In Table 4 there is one such illustration, where Student 3 gives an account that is vaguer than on the first occasion.

Table 4. Change of category

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 3</td>
<td>«I would check the pH of the river and bay. Then I would see how different pH's effect the growth of the coral.» (Category 4)</td>
</tr>
</tbody>
</table>

For 38 of the 80 students the answers were placed in the same category on both pre- and post-test. Most of these students’ answers were placed in Category 3 on both occasions. Pre- and post-test
answers in Table 5 show an example of the apparent continuity in the way many of these students answered on the two occasions.

Table 5. No change of category position

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 4</td>
<td>«I would use pH paper and test what color it becomes.» (Category 3)</td>
<td>«I would take some water and test the stuff with that pH paper thingy to see if there is a rise in the acidity.» (Category 3)</td>
</tr>
</tbody>
</table>

At a general level, the results give some indications that students improved their ability to use scientific terminology and produce a scientific-like narrative when reasoning about an environmental problem after interacting with the AOVL. The analysis of the students’ reasoning shows that 43,5 per cent of the students are categorized as giving a more elaborate answer on the second occasion, while 47,5 per cent keep to their original reasoning. Nine per cent of the students are classified on a lower level after working with the lab.

An interesting observation is that the wide age distribution does not seem to play any decisive role. The students in the older age group did not write more elaborate answers on either occasion. The younger age group (12–14) used more scientific terms in the pre- and post-test compared to the oldest age group (17–18). However, further studies are needed in order to investigate this particular issue.

Signs of a learning trajectory

As the data material covers an instructional period, it is interesting to see if there is any sign of a learning trajectory in the sense that students become increasingly familiar with what it means to conduct an experiment. At a general level, there is no clear evidence that students easily transfer their experiences when doing a virtual experiment to producing a written answer where they are to describe how to design a similar experiment. Most students already on the first occasion realize that the situation depicted in the problem requires some kind of “test.” Suggestions given are that one should «test the water» or «test the corals». This type of explanation is the one described as characteristic of Category 3, which is the most frequent classification in the material.

A frequent answer on the post-test is that the students explicitly mention that one has to study the effects of water status on the corals. This may be seen as a further specification of the reasoning in Dewey’s sense (Dewey & Bentley, 1949), since causality is included. This is the essence of Category 4, where 35 per cent of the answers end up on the post-test. Few students, however, end up in Category 5 where the procedures of a relevant experimental design are specified. But the learning trajectory of this sociocultural skill seems to imply a series of steps where one realizes that (a) one has to perform tests, (b) tests have to be informative and say something about how water quality/acidity affects corals, and, as a next step, that one is able to (c) describe a coherent experiment where factors are isolated and samples compared in such a manner that conclusions about the relationship between acidity of water and growth of the corals may be drawn.

However, there is another layer to the development that is interesting. Many students seem to respond by suggesting that one should do tests or observations when the fish hatchery has been built. Consider the following answer.
«You could test the pH before the hatchery opened and then test the ph after the hatchery opened and see the difference. If the pH has gone up and the fish and the coral are suffering or dying then the hatchery would need to be shut down or make some changes» (Pre)

This, in our view, signals something important about how a problem of this kind is understood, and how students position themselves when responding. Many students react to the problem primarily as an issue of whether the hatchery should be allowed to be built or not, or, alternatively, they argue that if it is built and the water deteriorates, the hatchery should be closed down. Thus, they respond as concerned citizens facing an environmental problem, rather than as someone who is to investigate a problem and provide information relevant to taking a decision. In our opinion this is an interesting observation, since it signals that in order to address the question as a research issue, one has to position oneself differently than when reacting to it as an environmental problem.

Discussion

At a general level, the results show that it is possible to identify signs of learning in students’ ways of picking up concepts and modes of reasoning regarding how to conduct experimentation after working with the virtual lab. More than 40 per cent of the students’ answers are more informative on the second occasion. Their use of terminology relevant for describing experiments increases somewhat in absolute (although not in relative) terms, and this could be read as a sign that some of the distinctions that concern the activity of doing experiments have been noticed. On the second occasion, more students explicitly argue that one has to systematically test the effects of different types of water on the corals in order to provide an answer (Category 4), and there are more students who describe an experiment that would provide the information asked for (Category 5).

At the same time, and as might be expected, the results show that the effects are far from uniform. Some students seem to profit, but for a substantial proportion of the students there are no or very limited visible effects on their performance on the second occasion. In fact, almost 50 per cent of the students respond in approximately the same manner on the two occasions and a small group (9 per cent) wrote less elaborate answers. Thus, a tool of this kind will not on its own do the job of making students understand experimentation. A teacher is very clearly needed in order to frame the activity. It is not enough to add technology of this kind to reach all students; rather it has to be embedded in a systematic pedagogical arrangement where it fulfils a specific function.

As argued in the introduction, it is not reasonable to expect dramatic effects on student understanding of the principles of experimentation from such a relatively short experience. Also, it must be remembered that to outline a study that would provide the information asked for is much more demanding than responding to questions by giving definitions or providing factual information. To describe an experiment in writing may be seen as a performative engagement with learning materials that is not always expected by students. However, to be able to outline an experiment could be regarded as a step in the process of understanding what the nature of science and scientific knowledge is, how research results are produced and validated; and this is, as we have argued paraphrasing Dewey (1966), different from learning about its end products only.

Furthermore, when producing a narrative outlining a research study, one has to actively produce a model in which terms and information are organized in a systematic manner so as to be relevant for answering a question within a reasonably coherent “thematic pattern” with concepts that derive their power through their interconnectedness as Lemke (1990) argues. The most interesting result, in our opinion, is the finding that a significant difference between the students is how their answer
is co-ordinated with the question asked, i.e., how students position themselves when answering. The problem is formulated as one of finding information relevant to whether a hatchery would have an effect on water acidity, or if this would not be the case. When looking closely at a clear majority of the responses produced by students, one finds that they, in fact, were answering slightly different questions. Some of the answers argue that the hatchery should not be built, or, alternatively, it should be built somewhere else. Others argue that the water might damage the corals. Many of the answers deal with the general relationships between water quality and effects on corals, but without contextualizing this as a matter of finding out by means of an experiment whether the hatchery should be built or not. Put differently, a major difference between the students concerns whether they (a) suggested a solution to the problem asked by outlining a study/an experiment that could resolve the issue ahead of building the hatchery, or (b) engaged in analysing the problem of what would happen to the water if the hatchery was built; or (c) engaged in a more general reflection on the nature of the relationship between water quality and coral growth. The difference reflects whether students position themselves as analysts of a problem in search of information that would serve as part of a decision-making process, or if they position themselves as citizens concerned about the environment. Differences in how students position themselves when answering such questions are also shown in previous research (e.g. Murphy & McCormick, 1997).

Rather few of the students answer in a way that reveals an understanding of how a scientific study could provide direct information on the issue by specifying in advance what would happen if the hatchery was built. Thus, when responding to the problem posed it is not enough to know about scientific concepts and experimentation, one must also realize how an experiment may address a particular concern, and what the role of a scientific inquiry could be for decision-making. If we connect the observations made to the wider issue of understanding experimentation as an element of science literacy, our study shows how, at group level, some improvement was obviously made in understanding the logic of experimentation. However, the important issue of how an experiment may provide an answer to a problem of the kind presented cannot be understood by reference to the experimental method per se – whether performed virtually or in the traditional manner. It is not by practising how to do virtual experiments – in the sense of manipulating symbolic information on a screen or working in a traditional school science lab – that one learns how to bridge between a problem and the information that an experiment could provide on a specific issue. Being able to bridge between a problem and the experimental method – i.e. engaging in inquiry in Dewey’s terms – requires a sequence of experiences where students encounter several examples of how such transformations of converting a problem into a relevant experiment take place. This is a discursive skill of thinking within a particular thematic pattern (Lemke, 1990), where one appropriates a mode of reasoning that allows one to formulate a research problem rather than reacting to an environmental problem.

This study forms a foundation for further investigation of which types of activities evolve when students engage in virtual lab work, and to what extent they are engaged in inquiry – transforming a situation that is indeterminate to something that is understood. Analysing how students engage with the virtual lab, and how this tool structures the interaction between students and between students and teachers, would add interesting information to understanding the product – student knowledge. It is still an open question in what sense students perceive virtual lab activities as lab activities, and whether they, when engaging with such tools, construe experimentation as a distinct mode of generating knowledge. Most likely, interactive support from the teacher will continue to play a critical role in fostering such understanding.
Acknowledgements

The research reported has been funded by the Marcus and Amalia Wallenberg Foundation and the Swedish Research Council and conducted within the University of Gothenburg Learning and Media Technology Studio (LETStudio), and the Linnaeus Centre for Research on Learning, Interaction and Mediated Communication in Contemporary Society (LinCS).

References


This was pointed out by Dewey already in his first version of *Democracy and education* from 1916 (Dewey, J. (1916). *Democracy and education. An introduction to the philosophy of education.* New York: Macmillan).

The analysis of the material implies that we were interested in how the students handled the problem of designing an experiment. There were 3 students in the original sample of 80 who in the post-test simply responded “The lab that we did in class” or similar. These students were exempted from the sample and 3 new students were randomly selected. The reason for this procedure is that although the answer is in some sense correct, the students are not responding to the assignment and it is hard to know exactly how they interpreted the problem.

Text in « » indicates an original quote from students’ writings. The illustrations here are taken from the entire sample of 469 students.
Comparison of Different Subject Cultures and Pedagogical Use of ICTs in Estonian Schools

Agnese Karaseva, Pille Pruulmann-Vengerfeldt & Andra Siibak

Abstract

This paper explores the ways in which teachers have integrated ICTs in teaching humanities and science classes at the elementary and primary school levels. The research is based in Estonia, looking at five Estonian and one Russian-speaking primary and elementary schools. Data were gathered through classroom observations and two consecutive interviews with 16 teachers. Our findings indicate that technology use is strongly related to the teacher’s dominant instructional style and the specific subject culture.

Keywords: pedagogic use of ICT, subject cultures, instructional styles, Estonia
Introduction

Schools worldwide are preoccupied with integration of technology, striving to intensify the use of computers and information and communication technologies (ICT) in teaching of all subjects (Ruthven et al., 2004). In fact, effective technology integration in schools is currently one of the most important issues in the EU, and also in various national agendas, for promotion of media and digital literacy. The latter, in fact, is seen as a lifelong skill and one of the key factors for citizenship in today’s information society (European Commission, 2007). A need for digital literacy skills is one of the reasons why many countries around the world have already implemented major curriculum reforms to integrate digital competencies in initial teacher training (Rizza, 2011), as teacher competencies and practices are central to the way ICT is adopted and used in the classrooms (OECD, 2001). In teacher competencies, the understanding of digital literacies lends itself to questioning how the ICT uses differ when looked at from the angle of subject-cultures. In this article we focus on literacies as practices that can be studied and compared through subject-culture lenses, enabling us to compare humanities and sciences teaching at stage I of basic education (grades 1–3) to the teaching of these subject cultures at stages II-III of basic education (grades 4–9).

We understand digital literacies not only as an individual skillset to be improved, but rather also as an institutionally and culturally dependent set of practices all of which have an impact on ICT use. For our analysis we have chosen the “how-to” approach (Buckingham, 2009), not trying to distinguish between “good” practices (constructivists) or “bad” practices (Sjøberg, 2007) of ICT use. We maintain the perspective of media literacy as a functional, instrumental skill where technology is used as a tool for learning – as a “teaching aid” (Buckingham, 2006). The other factors (e.g. the institutional context, peer influence, and personal factors like age, experience and gender) are seen as additional influencers of which we are aware, but on which we do not focus in this study. Hence we focus on subject cultures and teaching styles as two of the notably important social and cultural aspects strongly influencing literacy and ICT use across different subjects.

Our study was conducted with the aim of understanding how technology use in basic schools and general upper secondary schools in Estonia relates to specific subject cultures and teaching styles. We set out to compare the different subject-specific styles of ICT use to see if strong influences from perceived subject cultures are also visible in practice. Respectively, the research questions are:

- How are Estonian teachers implementing ICT in different subject teaching on the level of basic education?
- How do teachers’ practices of technology use relate to their instructional styles?

We believe that Estonia serves as an interesting case study for exploring the topic because it is a country which is often recognised internationally as a success story for its rapid change from being a post-socialist country to a modern democracy (Runnel, 2009; Reinsalu, 2008). These changes are acknowledged to be connected with the “internetisation” of the society (Kalmus et al., 2008). One of the best known symbols of such “internetisation” is the Tiger Leap programme which was launched in 1997 to adjust the Estonian education system to the needs of the development of the information society by equipping schools, connecting them to the Internet and training teachers in ICT skills (Runnel et al., 2009). In a few years, around 10,900 teachers out of 17,000 took ICT skills training courses offered by the Tiger Leap programme (UNDP, 2003). Since then Estonia has strived for a general education curriculum that focuses on integration of ICT in development of active teaching methods. The focus is being changed to the implementation of general skills and knowledge
in an integrated way, in which ICT is not taught as a separate subject, but blended into all subject teaching (Mägi, 2006).

**ICT and subject cultures**

We will analyse our empirical data, first, in the light of subject cultures, sometimes also referred to as subject subcultures and, second, in relation to the dominant teaching styles. Such a focus is dependent on the findings of previous studies that suggest that ICT may fit in with some school subjects more easily than others (Goodson & Mangan, 1995) and that use of computers in the classroom has links to teaching style (Zhao, 2004).

Authors define the subject culture as a “general set of institutionalized practices and expectations which has grown up around a particular school subject, and which shapes the definition of that subject as both a distinct area of study and as a social construct” (Goodson et al., 1995: 613). Explaining further, subject cultures are described as social frameworks or social communities (Hennessy et al., 2005) where specific sets of tools and resources, approaches to teaching and learning as well as cultural values, aims and expectations of teaching are shared. In addition, the subject culture can serve as a frame for “a shared vision for technology use and definitions of ‘good’ teaching”, in addition to which the subject cultures “can initiate and support meaningful technology use, particularly at the middle and high school levels” (Ertmer & Ottenbreit-Leftwich, 2010: 266–267).

This is especially important in the context where some of the teachers have also been referring to “subject boundaries” when explaining the choice of particular ICT tool (Hammond et al., 2011). For instance, John and Baggott la Velle (2004) reveal that science and mathematics teachers are more willing to integrate ICT in their teaching, because these subjects are perceived as more linked to technology. On the contrary, history teachers, when asked to explain the very limited use of ICT, refer to the “essential humanism at the core of the subject” (John & Baggott la Velle, 2004). English teachers, however, have been reported to show anxiety about “losing the core features and values” of their subject – classroom discussion and use of printed books (Hennessy et al., 2005). Other authors (John, 2005) have also indicated that teachers have expressed their concerns about technology “becoming the message”: by using ICT the core idea of obtaining knowledge in a particular subject is replaced by simply playing with technological means. It should be remembered, however, that these different approaches evolve not only in the context of each particular subject, but also in the institutional context of a particular country or school.

**ICT use and teaching style**

There is a notable body of research revealing the different approaches to and motives for ICT usage in pedagogic practice, in which scholars have sought to reveal the most influential ones affecting the integration of ICT at primary and secondary educational levels. In addition to the three groups of factors which influence the teaching process and technology use in classrooms – availability of infrastructure, contextual factors and personal factors – various studies (Buckingham, 2006; DeVries & Zan, 2003) report that the dominant teaching style and the perceived role of the teacher in the classroom can also be directly linked to the use of ICT in schools. We see these factors in interaction with each other and as formulating a set of literacies for the teachers.

In fact, research indicates that use of ICT often depends upon the established pedagogical practice (Baggott la Velle et al., 2003). Technology in this context is an important part of altering the teacher–
learner relationship, thus redefining the role of the teacher and his/her teaching style (Grasha & Yangarber-Hicks, 2000). Although some authors argue that the technology integration alone does not ensure a shift to more student-centred instructional styles (Palak & Walls, 2009), others suggest that the instructional style may alter, according to the learning goal (de Kock et al., 2004) or the age of the students (Zhao, 2004). For instance, when working with younger students, teachers are found to prefer having more control over what the student does with the technology and in deciding what tools and resources must be used, including giving specific websites to visit and specific guidelines to follow (Zhao, 2004).

For our empirical data analysis, we were looking for existing frameworks or classifications of instructional styles. We relied on the framework provided by Zhao (2004), whose continuum of technology use in the classroom consists of four dominant instructional models:

- in the teacher-centred model, mainly PowerPoint presentations are used, actually just substituting for printed textbooks;
- in the teacher/technology-guide model, teachers use WebQuests, simulations and games, giving a little more space for individual student work;
- in the student–teacher negotiated method, students are given much more independence in using the technology to complete project-type tasks were they can demonstrate in-depth comprehension. In this model, the role of the teacher is to guide student work by giving the assignment, defining research topics and introducing useful web resources;
- in the student-centred model, students become the active information explorers and presenters. Teachers have the role of facilitators of the process and guides for advising the useful resources and tools to accomplish the planned work. Numerous combinations of technology can be used.

Our empirical section will look at the emergence of these models in different classroom situations with an attempt at comparison if these also correspond to the level of teaching (stage I or stages II-III at the level of basic education) and the subject being taught (humanities or sciences).

Methods and data

Setting and Participants

Data collection for this paper comes from three stages: (a) in-class observations, (b) short semi-structured interviews with teachers immediately after class, (c) longer semi-structured interviews with teachers 6–8 months later.

Our sample consists of 16 teachers from five different schools around Estonia, who all teach different subject areas at the level of basic education, either in Estonian or Russian-speaking schools (see Table 1). All the teachers in our sample had passed ICT-related training courses offered by the Tiger Leap Foundation and appreciated practical training programmes that had provided them with ICT related skills and concrete suggestions for incorporating the technologies into everyday teaching. Nevertheless, our aim was to capture as wide a variety of different classroom practices related to ICTs as possible. The list of schools participating in the various training programs and activities organised by the Tiger Leap Foundation was taken as the basis for forming the sample for this study. Hence, in addition to differentiating between schools in bigger cities and schools in rural areas, we also differentiated between schools which had been quite active in taking part in various
ICT related initiatives organised by the Tiger Leap Foundation, schools that had taken part in some of those activities and schools whose teachers had no connection to ICT related training courses and activities.

Table 1. Overview of the sample

<table>
<thead>
<tr>
<th>Subject</th>
<th>Total</th>
<th>Of them in schools with a strong connection to Tiger Leap Foundation</th>
<th>Of them in schools with a mild connection to the Tiger Leap Foundation</th>
<th>Of them in schools with no connection to Tiger Leap Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class teacher (all subjects for 1–3 graders)</td>
<td>5</td>
<td>2*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sciences teacher (math, physics, chemistry, biology, geography)</td>
<td>5</td>
<td>2*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Humanities teacher (history, foreign languages)</td>
<td>6</td>
<td>3*</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*One of the schools was a Russian language school.

In September 2011, we sent an e-mail to the schools asking them to participate in the study. The schools which responded positively to our request were asked to suggest one teacher of humanities, one of sciences, and one class teacher from their school who were accustomed to using ICTs in everyday teaching, and would be willing to participate in the study. Therefore, our final sample consisted of teachers who might be more experienced and active in using ICTs in their everyday teaching, compared to the others in their school. Furthermore, our sample was heterogeneous also in terms of the teaching experience: all of the teachers in the sample had been working in school for at least three years; however, some of them also had more than 20 years of teaching experience. The teachers in our sample also had different opportunities in terms of ICTs they could use for teaching. All teachers had access to computer labs, and could also use data projectors, Smart Boards and in some cases tablets. However, none of the teachers in our sample had simultaneous access to all three additional technologies.

Data Collection

In the first phase of the study, in autumn 2011, in-class observations by two observers were conducted for two lessons per teacher (see Table 2). During the observations we aimed to find out what kind of ICTs are used during the class, by whom and for which activities. Furthermore, we aimed to observe how the instructional style of the teacher varies in respect to the assignments given and the materials used.

In the second phase of the study, short semi-structured interviews were carried out with each teacher directly after the observations. Exceptions were class teachers, as they usually gave two consecutive lessons and were interviewed after the second lesson. During these short interviews, the teachers
were asked to reflect upon the lesson that had just finished – if everything had gone according to
the plan; if the teacher was satisfied with the way the lesson had turned out; etc.

Table 2. Overview of the lessons for in-class observations

<table>
<thead>
<tr>
<th>Subject</th>
<th>Stage I of basic education (grades 1–3)</th>
<th>Stage II of basic education (grades 4–6)</th>
<th>Stage III of basic education (grades 7–9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanities</td>
<td>Mother tongue 4</td>
<td>Mother tongue* 3;</td>
<td>German 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>English 3</td>
<td>History 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>History 2</td>
<td></td>
</tr>
<tr>
<td>Sciences</td>
<td>Mathematics 2</td>
<td>Mathematics 2</td>
<td>Physics 2</td>
</tr>
<tr>
<td></td>
<td>Biology 2</td>
<td>Biology 1</td>
<td>Geography 1</td>
</tr>
<tr>
<td>Classes attended for observation</td>
<td>8</td>
<td>11</td>
<td>7</td>
</tr>
</tbody>
</table>

*In two cases the mother tongue was Russian.

In spring 2012, in the third phase of the study, hour-long interviews with all of the teachers were
carried out. The interviews focused upon various topics – the teachers’ self-assessments of their
computer knowledge and skills; their perceptions about various opportunities and risks related to
using ICTs; their own in-class ICT usage practices and ICT-related assignments they usually gave
to the students. In the article at hand we will concentrate on the two latter aspects.

All the interviews were conducted in the mother-tongue of the respondents – 13 in Estonian and
three in Russian. All the interviews were audio-taped and transcribed. Extracts from the interviews
were translated by the authors to illustrate the analysis.

Data Analysis

Researchers’ field notes from the observations were compared and open coded, and later
conceptually similar phenomena were grouped to form categories and subcategories.

In coding the interview data we considered only those utterances that concerned ICT use in the
classroom, home assignments and instructional styles. In looking for the comparable differences in
subject culture, we analysed separately both the interviews as well as the observation field notes for
science (e.g. math, physics, chemistry) and humanities teachers (e.g. languages, history, civics) and
the class teachers who teach all subjects for grades 1–3.

Results and discussion

While our sample is not particularly big, the differences in the data still allow us some comparison
between different groups of teachers. Hence we present our results based on the subject areas,
looking at science and humanities teachers separately from the class teachers.
The use of ICT in science classes

The analysis of our data suggests that the teacher-centred model and teacher/technology-guide model (Zhao, 2004) are most dominant instructional styles when incorporating ICTs in the science classes.

When incorporating a teacher-centred instructional style (Zhao, 2004), the science teachers in our sample used Smart Boards or PowerPoint slides to substitute for printed textbooks or exercise books. Our in-class observations indicate that only a few students per lesson (if any) are asked to do an exercise on the Smart Board directly. Rather we observed that while the Smart Board was used to demonstrate new knowledge, exercises that followed were done either with pen and paper or on the traditional blackboard next to it.

All the science teachers in our sample used various interactive online tests and spread sheets to help the students revise or prepare for tests. When incorporating the teacher/technology-guide model (Zhao, 2004), students were given more time for individual work with the ICTs. Our interviews with science teachers reveal that the most frequent ICT-related assignments that teachers set had to do either with searching for or accessing information on the Internet, and making (PowerPoint) presentations, whereas taking tests in an online environment or using e-mail to send in a home assignment were mentioned less often.

The most usual [student assignments involving ICTs] are searching for information, compiling a literature review and these kind of things, especially in physics. (Physics/Maths teacher)

We were both told in the interviews and were able to observe in the classrooms that the use of topic-specific software gave the students the opportunity to witness or carry out real life experiments. Physics and chemistry teachers, for example, made use of LabQuest technology and software which enables the collection and sharing of data from various experiments; while mathematics teachers found GeoGebra and T-algebra software with its interactive graphics and algebra applications useful. In addition to the specific educational software, YouTube resources were used to demonstrate experiments that cannot be carried out in ordinary classroom settings. For instance, one of the physics teachers showed a YouTube video in class to illustrate how lenses operate, while a maths teacher introduced the topic of triangles by showing the students a documentary about the Bermuda Triangle. The last example demonstrates the attempts to bridge traditional subject cultures, which in Estonia would largely focus on repetition of theorems or definitions and repeated practice solving of maths problems.

The science teachers in our sample also claimed to use different platforms (e.g. Viko, Moodle, E-kool) for record keeping, student assessment and data storage as well as for preparation, management and administrative purposes. These online environments are also used in order to communicate with students about their home assignments or other distribution of study materials. Some of these platforms are used mainly in accordance with the general school rules, and teachers have been forced to adopt record-keeping or student assessment-related ICT use based not on their own interests, but rather as part of the general institutional culture.

Although all the interviewed teachers claimed that usage of ICTs has a positive impact especially in terms of engaging students with the topic, they also declared that in their teaching they would not want to rely only on ICTs. In fact, all of the interviewed science teachers referred to the fact that...
they would rather use the ICTs once in a while and combine them with various other elements, e.g. doing assignments on paper or on a blackboard.

Well, my dream would of course be that you need not go to the computer lab [to use the computers] but have them [the computers] on my own classroom tables. /---/ That if the computers were on my own classroom table then there would also be enough room to do [assignments] with a textbook and notebook, and then for a while with the computer … that would be a much better option, compared to planning the whole computer-based lesson.
(Maths teacher)

Due to the fact that in the majority of Estonian schools the students do not have their own in-class laptops or tablets, the science teachers usually need a computer lab to carry out lessons involving interactive assignments. Some of the science teachers in our sample however also referred to the problem of “de-contextualization” (John, 2005) of the subject, which is the result of the need to work in a computer lab instead of the usual study environment where the subject is taught. Furthermore, the teachers admitted that due to the specific layout of the computer labs, they often found it difficult to mix interactive programmes with other, more traditional teaching equipment. In the observations, we could also witness the reluctance of the students to use pen and paper to do some of the maths before entering the correct answer in the teaching software. Rather, they chose to engage a fast-paced trial and error game, appropriating the learning software in a very different way from its intended use.

The use of ICTs in humanities classes

Our interviews and in-class observations indicate that in case of humanities classes, the technologies are used for mixed purposes: (a) to complete written work, edit, check the results, find necessary information online, etc.; (b) to improve the instruction process – diversify the methods of tutoring, and (c) to give the students the possibility to collaborate with peers, develop critical thinking, etc.

Language teachers in particular used interactive white boards as well as online and offline whole-class games (e.g. Jeopardy, Alias) to help students memorise previously taught vocabulary, as well as to raise the engagement level and interest of students. Furthermore, ICTs were also used to give students the possibility to complete and format texts, or fill in various grammar exercises. In-class observations also show that language teachers are more likely to invite students to fill in such exercises in on the interactive boards.

At the same time, interviews with the humanities teachers indicate that they still prefer to use ICTs as a reward after completing certain tasks, rather than on an everyday basis, making ICT use a privilege rather than seamlessly integrating it into classroom activities.

/---/ When I say that we have a lesson in the computer lab today, then this is for them [the students] very like oohh, they are all so happy, like “oh yes, now I can use the computer”, that I would like this to stay like … like a reward for them, or like, they are happy to go there … (English teacher)

In addition to incorporating the teacher/technology-guide model of instruction, humanities teachers also made use of both the student-teacher negotiated model of teaching and the student-centred model (Zhao, 2004). In the former case, students were given various project-like creative assignments. For instance, the German language teacher had asked her students to make a video about German fairy tales, whereas the history teacher had led her students to make a photo story of the buildings they considered to be most important in their hometown with the aim of introducing
them to a certain period in Estonian history. Furthermore, all the humanities teachers in our sample had also asked the students to make either individual or in-group a PowerPoint presentation, which serves as another example of the approach supporting the social aspects of learning.

In the student-centred teaching projects, however, the students were given a chance to become active information seekers and presenters. For example, an English teacher had asked the students to search for useful grammar exercises from the net; whereas in the civics classes, one of the teachers made use of an online learning environment where the students could upload their home assignments and were advised to comment upon the works of others.

History teachers, however, were active in making use of online resources both for information seeking as well as to organise students’ individual work. The history and civics teacher in our sample, for instance, had used online sources and additional educational software to get her students actively engaged in a specific topic. For example, she had asked the students to draw a (three-dimensional) timeline of a specific historical area; to draw a mind map and a concept map related to historical events; and to make use of a photo story programme to compile a photo presentation on a topic.

I tell [them] to make a cartoon about a specific century, so that one needs to investigate and to create and to think it through: what is it about that period that they want to highlight; or to draw a timeline about Estonian history from the thirteenth century to the present day; and they do it; what we would otherwise be doing an a blackboard, now on a computer, right. (History/Civics teacher)

The humanities teachers interviewed were also well aware of the various international teacher resources and platforms, e.g. OnestopEnglish, which they could use both for inspiration and materials; and also made use of different online environments (Moodle, Viko, Google sites) to upload their own teaching materials.

The use of ICTs by class teachers

Our findings indicate that class teachers matched their instructional styles to the particular subject they were to teach. A similar observation can often be made in their instructional use. For instance, in the case of maths lessons, exercises and repetition were emphasised, whereas in the case of mother tongue or language lessons, more creative uses were employed, as class teachers in our sample also stressed the importance of games and playfulness in the class.

They [students] are given some kind of an assignment which they need to solve in a group, or there is some game that they can either play with a partner or in a group; these kind of assignments are very common already from the first grade onward. (Class teacher)

Our findings indicate that class teachers also actively combine different technologies. For example, voice recorders were used during a reading assignment so that the students were able to listen to their pronunciation afterwards. In addition, new applications and the possibility of using tablet computers have opened up the range of educational resources available for teachers, all of which are increasingly incorporated in elementary school instruction.

Class teachers also favour ICTs as a way to incorporate other voices than their own in the class. For instance, they show films or videos to demonstrate diversity of voices, both from the perspective of different opinions, as well as to demonstrate the beauty of the language or voices from nature.
When it comes to home assignments and online learning environments, class teachers are usually careful to note that not all students have equal access and hence home-use is carefully regulated. Only one teacher from the countryside mentioned that she uses home assignments that require ICT use, but that she encourages students to work together so that those who have limited access to the Internet can get help from classmates.

Discussion

Our in-class observations and interviews with Estonian teachers indicate that in comparison to the science teachers, whose existing instructional style and technology integration by itself does not seem to ensure the shift to more student-centred instructional styles (Palak & Walls, 2009), the humanities teachers in our sample combined a wider variety of instructional models. In fact, our data indicate that the instructional style of the language, history, and civics teachers in our sample covered the whole continuum of technology use in the classroom as proposed by Zhao (2004).

In comparison to the humanities teachers, who were more open in using the technologies to conduct student-centred learning approaches, both when conducting pre-set project based tasks and also when managing student-led exploration-type assignments, the science teachers in our sample mainly relied on a teacher-centred instructional style (Zhao, 2004). In other words, they were accustomed to using Smart Boards or PowerPoint slides to substitute for printed textbooks or exercise books. Hence, as demonstrated by Crisan, Lerman & Winbourne (2007: 35), who explored secondary school mathematics teachers’ classroom practices in the UK, science teachers in our sample also tended to use the ICTs predominantly so as to “realise their established form of practice”. In a way, this contradicts common assumptions that science teachers would feel more comfortable in engaging students with technology, as when choosing assignments humanities teachers in our sample were somewhat less concerned about the technology skills of the students.

Furthermore, similar to the findings of Passey (2006) our results suggest that even when there is a chance to make use of an interactive whiteboard, the science teachers in our sample seldom allow students to touch the screen and work with the board directly. At the same time, the students were given their chance to try and fail through another approach – similar to the secondary school science teachers in Norway (Wikan and Molster, 2011), the science teachers in our sample were eager to make use of ICT based simulation modules.

Learning through fun and games, however, was a frequent strategy used both by the humanities teachers as well as class teachers in our sample. According to Zhao (2004), playing in-class games can, on the one hand, be seen as a method of relaxation, while on the other hand it also serves as means of obtaining knowledge in an informal way. Hence, in comparison to the previous studies (e.g. Zhao, 2004) which suggest that the teacher’s instructional style is more controlling when working with younger students, class teachers who teach all subjects for grades 1–3 appeared to be significantly more open to student-centred projects. In fact, our in-class observations and interviews indicate that, in a similar way to reflections from Dutch primary schools (Smeets, 2005) the use of ICT tools by class teachers in our sample contributed significantly to the creation of an authentic (reflecting the potential use of acquired knowledge, with links to the world outside the school) and powerful (involving active knowledge construction, differentiation according to students’ individual needs rather than transmission of facts) learning environment for students.
The instructional styles incorporated by the humanities teachers in our sample, however, emphasised the importance of social learning, i.e. similarly to the findings of Lin, Wang & Lin (2012), the teachers aimed to enhance students’ learning through their social relationships and interactions with the outside environment. In fact, our findings suggest that the humanities teachers made use of cognitive active learning (ibid.) techniques so as to engage the students actively in the learning process and get them cognitively engaged with the study materials.

Hence, contrary to a Finnish study (Ilomäki, 2008), which revealed that despite having a good command of ICT, Finnish teachers still lack vision about meaningful ways to use technology in pedagogic practice, the teachers in our sample demonstrated rather creative and playful ideas when incorporating ICTs in their classes. Indeed, as our sample was recruited through the Tiger Leap research project, knowledge of ICTs was a prerequisite to participate in the study. Nevertheless, even the ICT usage practices of those teachers who had had less contact with ICTs and whose school had not taken part in any of the training programmes or activities offered by the Tiger Leap Foundation, made considerable effort to applying ICTs in meaningful ways to complement their personal teaching styles.

Furthermore, previous studies have reported that the integration of ICT into the teaching of different subjects is very time- and effort-consuming (Baggott la Velle et al., 2003). Although similar complaints were also made by the teachers in our sample, the participating teachers were generally quite well aware of the various international teacher resources and platforms and some of them were also eager to upload their own teaching materials online.

All in all, our analysis demonstrates a strong linkage of the existing disciplinary culture and instructional styles to ICTs, meaning that it would be very hard to contradict existing modes of instruction in the effort to enhance literacies and widen the repertoires of ICT use in classrooms. As mentioned in our sample description, our teachers appreciated practical training programmes that had provided them with ICT-related skills and concrete suggestions for incorporating the technologies into everyday teaching. We can assume that the training provided for them linked nicely to their existing teaching styles, and as the training programmes often focus only on ICT use rather than broadening repertoires of instruction, teachers adopt those practices that are already familiar to them. Our study enables us to ask whether, in order to enhance the teachers’ digital literacies, helping them to overcome “subject boundaries” (Hammond et al., 2011) might be the key. Providing teachers with possibilities of diversifying their teaching style and supporting changes in subject culture might be beneficial in broadening the horizons and in the long run supporting teachers’ digital literacies. Digital literacy as a practice can be enhanced by broadening the repertoires of ICT use and better incorporating the understanding of literacies in the social and institutional context of the teachers.

While the focus of this article has been on teaching styles and subject cultures as key influencers of digital literacy, we still feel that it is crucial not to forget other aspects. We hope that in future studies more of those different aspects can be brought together and in-depth analysis will enable us not only to assess the relative importance of each of those factors, but also to map the diversity. Only when understanding the complex nature of digital literacy can we adequately support members of an ICT-saturated society in their acquisition of these practices.
Acknowledgements

The authors are grateful to the Tiger Leap Foundation for financing the study *Effect of teachers’ ICT use activity on pupils’ knowledgable use of technology* and grateful to the Estonian Research Council for the support of the project PUT44.

References


Mathematical Learning Opportunities in Kindergarten through the Use of Digital Tools: Affordances and Constraints

Martin Carlsen

Abstract

This study aims at scrutinising the mathematical learning opportunities of children engaging with digital tools and the emerging affordances and constraints faced in such settings. By adopting a sociocultural perspective on learning and development, the multimodal analysis of the adult–child interaction shows that the children are participants in processes of appropriating the mathematical concepts of sorting and counting. Affordances are taken advantage of by the adults and constraints causing didactical dissonance are overcome and transformed into didactical harmony.

Keywords: Appropriation, Digital tools, Kindergarten, Mathematics
Introduction

According to OECD (2006), Norwegian kindergartens are educational institutions situated within a social pedagogy tradition as opposed to a “ready for school” approach. The enterprise of the kindergarten thus comprises play, care, and learning. During the last decade, mathematics has gained increased emphasis in curriculum documents related to the kindergarten context. The Norwegian Ministry of Education and Research (2006a) launched a framework plan in which mathematics for the first time was addressed as a separate domain. Norwegian authorities (Ministry of Education and Research, 2006b) have also emphasised the importance of implementing the use of ICT in the kindergarten to nurture children’s development of digital literacy (see Buckingham (2006) for an in-depth analysis of digital literacy). However, these documents do not explicitly address issues regarding how to orchestrate mathematical activities through the use of digital tools.

In 2010, a project called ‘ICT supported learning of mathematics in kindergarten’ was initiated at the University of Agder (UiA). In the project, two colleagues and I collaborated with kindergarten teachers in their orchestration of digital tools to foster children’s mathematical learning processes (Hundeland, Erfjord, & Carlsen, in press). Both web-based applications and DVD-based software were explored and used with interactive whiteboards (IWB) and computers. In our work we were inspired by the argument of Plowman and Stephen (2003) and Sarama and Clements (2004), that research is needed which aims at identifying the role that digital tools may play and how such tools may contribute to mathematics learning. This argument was repeated by Goodwin (2008), that research is lacking in the intersecting areas of mathematics, kindergarten children and use of digital tools.

A national survey in Norway with respect to children zero to six years old and their experiences with digital tools (Guðmundsdóttir & Hardersen, 2012) showed that these children live in a digital universe and they have experience with a broad spectrum of digital tools. My hypothesis is thus that kindergarten children may gain from their experience and engagement with digital tools as regards their learning of mathematics. The scope of my study is to investigate the possible mathematical learning opportunities which emerge when children engage with digital tools in the kindergarten, and the role of the adult(s) in that respect. More specifically, the following research question has been formulated for the present study: In what ways does use of digital tools in kindergarten give mathematical learning opportunities with respect to sorting and counting?

Theoretical framework

In this study I adopt a sociocultural perspective on learning and development, a theoretical stance originating from the work of Vygotsky (1978, 1986) and later socioculturalists such as Rogoff (1990, 1995), Säljö (2001, 2005), Wells (1999) and Wertsch (1998). Within this stance the notion of appropriation is used to denote the process of learning. According to Wertsch (1998), appropriation is a process of “taking something that belongs to others and making it one’s own” (p. 53). Furthermore, Rogoff (1995) describes appropriation as occurring in the process of participation in a sociocultural activity “as the individual changes through involvement in the situation at hand” (p. 153). Appropriation is hence fundamentally intertwined with participation in collaborative practices (Vianna & Stetsenko, 2006). As argued elsewhere (Carlsen, 2010) in order to be involved in a process of appropriating a mathematical tool such as the number concept, the child has to be involved in a joint activity with more capable peers. The child also has to establish with peers a shared focus on what to pay attention to in tasks involving the number concept, and develop with peers shared
meanings of the concept and appurtenant mathematical ideas. Furthermore, the child has to identify relations between her individual sense of the concept and the lexical meaning of it. Eventually, the child has to be involved in a process of transforming, i.e. to appropriate utterances and actions made by fellow children and adults in collaborative settings, and apply these in future activities (Moschkovich, 2004; Rogoff, 1990; Radford, 2002, 2003; Säljö, 2005).

The use of cultural tools, such as web-based mathematics applications in institutionalised settings, carries affordances and constraints when viewed from the user’s perspective. According to David and Watson (2008), ‘affordance’ is a notion denoting “the possibilities for interaction and action offered in a classroom” (p. 32). Constraints are, accordingly, the “norms, effects and relations which limit the wider possibilities” (p. 32). Thus, affordances open up for interaction and action while constraints restrict interaction and action. I adopt these notions to analyse the affordances and constraints of the children’s participation in a kindergarten setting, and how these affordances and constraints unfold as related to the quality and level of difficulty of the applications, technical issues, the children’s behaviours, and child-adult interaction.

The multimodal nature of the children’s interaction is crucial when it comes to their opportunities to appropriate the mathematical tool. From a theoretical point of view, the accompanying modes of interaction such as dialogue (Linell, 1998), gestures, body movements, nodding, and gaze (Radford, 2003; Roth, 2001) are seen as fundamental when analysing the appropriation process. In a study of kindergarten children’s processes of appropriating number concepts by way of multi-touch technology, Ladel and Kortenkamp (2013) argue that the digital tool the children interact with significantly supports their externalisations of thinking. The digital tool becomes a tool for externalising thoughts and ideas related to both cardinal and ordinal aspects of the number concept. In their study, Ladel and Kortenkamp view the process of learning (mathematics) as involving the use of gestures. The digital tool these authors use affords touching and manipulations of screen objects. Gestures thus are naturally used by the children to make their mathematical thinking explicit. Research on the role of gestures (e.g. Goldin-Meadow, 2009; Radford, 2003; Roth, 2001), shows that gestures are used by children as mediating tools in order to communicate and emphasise ideas and thoughts.

Researchers such as Vangsnes, Gram Økland, and Krumsvik (2012) have shown that when commercial educational computer games are used in kindergartens, a didactical dissonance emerges between the game’s learning space and the learning space which the kindergarten teacher seeks to achieve. In their study, Vangsnes et al. reveal that the studied kindergarten teacher found it problematic to realise her aims in using the game, due to the game’s nature and internal didactical dispositions. In my study, the issue of didactical dissonance is not as striking as in the study of Vangsnes et al. In the study presented here, the web-based applications engaged with are argued to differ in nature from what Vangsnes et al. call commercial educational computer games. In my study, the adults orchestrate the children’s engagement with an application designed for mathematical learning, which enables didactical harmony. However, we will see that the adults take active roles in their interaction with the children in order to overcome the didactical dissonance. The adults focus on specific mathematical learning goals to make the children’s interaction with the digital tool a mathematically meaningful learning activity.

Methods of data collection and analysis

The study presented here is of a qualitative nature (cf. Cohen, Manion, & Morrison, 2011). One basic assumption for my research was to study what happens when children interact with digital
tools in a kindergarten setting. Two sessions lasting approximately 30 minutes each were videotaped in which four children five years of age, two girls and two boys, participated and were engaged with digital tools. The two boys worked collaboratively with web-based applications on a portable computer with a mouse, and the two girls worked collaboratively with web-based applications on a computer with touchscreen, however in separate rooms. The reason for dividing the children into two homogeneously composed groups with respect to gender was that the two boys were friends and the two girls were friends. No particular reason was given concerning which group was to use the various equipments. A pragmatic decision was taken that one group had to use the portable computer and the other group had to use the touchscreen. In both sessions, the children interacted with an adult who orchestrated the activities, i.e. he set up the activity with computers, guided the sessions, commented and asked questions to the children and so on. All four children had previous experience with using computers, but none of them had engaged with the particular applications that were used for this study. Naturally occurring talk-in-interaction was thus video recorded and transcribed in detail. This was done to serve an in-depth analysis of the interaction and collaboration involved in the children’s processes of appropriating the mathematics implicitly present in the applications.

The digital tool the children engaged with for this study was a digital learning resource associated with a Norwegian mathematics text book called Multi (http://web3.gyldendal.no/multi). Both the boys and the girls interacted with applications designed for Norwegian second graders. This means that the children worked with mathematical tasks originally meant for children who are two years older than they were. As will be evident, the children are able to interact with and solve the mathematical tasks when competently supported by the adults.

The analytical approach I am adopting for this study is partly similar to that of Lantz-Andersson and Linderoth (2011). I am taking a multimodal approach (Radford, 2003; Roth, 2001) to the analysis of video data. The basis for my analysis has thus been that every utterance gets its meaning from its positioning in a sequence of utterances, i.e. each utterance ought to be interpreted relative to preceding and consecutive utterances. Furthermore, the utterances are parts of a jointly constructed dialogue made and experienced by all contributors (Linell, 1998). However, both verbal and non-verbal contributions complement each other, and therefore multimodal analyses are made regarding the role of the children’s verbalisations and gestures when interacting with each other, the adult, and the digital tools. This combined approach encompasses the view that the interaction occurring amongst the children, the adult, and the computer is in essence multimodal. Moreover, the affordances and constraints within this multimodal process of interaction are considered when analysing the children’s plausible opportunities when using digital tools in the kindergarten context.

Analysis and results

In the following excerpts, the children interact with web-based applications related to the mathematical theme of descriptive statistics, i.e. in this case sorting and counting. However, the children need to make sense of the multimodal nature (cf. Roth, 2001) of the applications, with text, diagrams, number symbols, pictures of toys, and movement. Moreover, the children have to relate to each other as well as the comments and questions by the adult. Excerpts will be presented originating from two settings: (a) two boys and an adult are interacting with the application, with the part called “Column diagram” at difficulty level 1; (b) two girls and another adult interact with the application, with the part called “Falling toys” at difficulty level 3.
Excerpt 1: Making sense of the application

In the following excerpt, the boys are engaged with an application displaying a diagram and symbolic toys to sort; see Figure 1. The children are supposed to sort the bricks according to their colour and relocate them in the columns to the right. In Norwegian the word “bricks” is written, even though the displayed geometric shapes are coloured squares. After sorting the shapes, the children may press the OK-button to check whether they have done the sorting correctly.

![Figure 1. A web-based sorting activity, level 1 (Author’s translation in the text box)](http://web3.gyldendal.no/multi/1-4nettoppgaver/multi2a/kapittel3/oppgaveA/nivaa1)

The dialogue below, lasting two minutes, involves Leo, the adult, and the two boys John and Jack. Leo’s goal for engaging the children with this application was for them to use the digital tool to experience sorting, counting, and realise the numerical relation between number and associated numerals.

<table>
<thead>
<tr>
<th>No.</th>
<th>Person</th>
<th>Words spoken</th>
<th>Non-verbal activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leo</td>
<td>Now we are going to do something fun, and you are going to do that interchangeably. Firstly, John is going to do it, and after that Jack is going to do it. Because now we are going to look at these quadrilaterals here, these squares, the green ones, the blue ones and the yellow ones. Then we are going to move them over here afterwards. We have to find out how many they are. I wonder how many GREEN quadrilaterals you can find here?</td>
<td>Points at the right hand side of the screen</td>
</tr>
<tr>
<td>2</td>
<td>John</td>
<td>Four</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Leo</td>
<td>Yes, four. And how many blue ones are there?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>John</td>
<td>Three</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Leo</td>
<td>Yes, three. And how many yellow?</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>John</td>
<td>Two</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Leo</td>
<td>Yes. Now I want you to stack all the yellow ones here. I will show you how to do it. I take <em>it</em> <em>there</em>, press, drag and drop it <em>there</em>. Are you able to do this with <em>that one</em>? Can you use that mouse?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The mouse cursor Above one of the yellow squares At the left column Points at the other yellow square</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>John</td>
<td>Carries out the drag-and-drop action explicated by Leo</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Leo</td>
<td>Yes, like that, press(...) Great(...) And then we are going to take the blue ones. Can you do that too? All the blue ones over there?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Points at the column in the middle</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>John</td>
<td>Removes the blue squares and stacks them in the middle column. Some small comments are made by both Leo and John regarding the displacement, e.g. oops, like that. Leo instructs John how to do the displacement technically, to press and to hold the mouse button while dragging the square</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Leo</td>
<td><em>Here</em> we need to write some numbers. We have to write: how many were there of the yellow ones? Do you remember?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>When finished with removing all squares and stacking them in the three columns, a text box emerges below each column Points at the text boxes</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>John</td>
<td>Two</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Leo</td>
<td>Yes. Are you able to locate the numeral 2 <em>here</em> and write 2?(...) Somewhere up <em>here</em> you will find the numeral 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Points at the keyboard Slides his finger above the numerals in the upper part of the keyboard</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>John</td>
<td>Hm(...) It is next to 1</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Leo</td>
<td>Is it next to 1?</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>John</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Leo</td>
<td>Yes, that was correct. Then we are going to do <em>this</em> one</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clicks the cursor in the next text box, below the middle column</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>John</td>
<td>Three</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Leo</td>
<td>Good, and then it is the last one</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>John</td>
<td>Four</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presses the 4-key</td>
<td></td>
</tr>
</tbody>
</table>
In this excerpt it is evident that a learning activity is initiated by Leo when he starts by explaining what to do with the application (1). Leo situates the activity as being about estimating the number of squares of different colours and sorting the squares according to colour. John makes sense of the instruction and he answers Leo’s question immediately (2). The strategy for counting the green squares cannot be detected explicitly from the video. However, I interpret the video as indicating that John is exemplifying the phenomenon of subitizing (cf. Fisher, 1992), i.e. the phenomenon that a person may only by a short gaze estimate a number without counting one by one. However, it might be that John is counting by moving his gaze, since he is neither pointing at the squares with his finger nor with the mouse cursor. This situation is repeated for all three colours (2, 3, 4, 5, 6).

Then the dialogue continues, directed towards the sorting and stacking activity of the squares (7, 8, 9, and 10). Based on his actions, John (8, 10, 12) has no difficulties with the sorting of squares according to their colour. However, he seems to have some technical-motoric difficulties with the physical displacement of the squares. After finishing the stacking of squares in the columns, Leo seeks to focus the attention on the correspondence between the number word two and the numeral 2, and he asks whether John can locate the numeral corresponding to two (13). At first, John has difficulties in locating the numeral 2 amongst all the keys, since some seconds go by without any action (14). Eventually, he externalises that he has appropriated some ordinal aspects of the number concept, because he makes explicit that he knows that 2 is next to 1. From the context it is reasonable to interpret this utterance as revealing his knowledge of these numerals as located next to each other on the keyboard (as the corresponding number words are next to each other in the number series). When he has located the numeral 2 (16), it is easier for John to locate the numerals 3 (18) and 4 (20).

In this excerpt we see how the adult orchestrates the learning activity by using the application as a mediating tool to communicate and interact with the children. From the outset it is apparent that the adult is dominating the conversation. The child contributes solely with short oral statements. However, the child’s contribution first of all takes place as actions with the mouse, stacking the squares by dragging and dropping. In spite of this, a dialogue as a medium of learning is jointly achieved by Leo and John. The affordances emerging through the use of the digital tool are, I would argue, prevalent features (cf. David & Watson, 2008). The digital tool affords opportunities for interaction, foremost between the adult Leo and one of the children John. It is evident that John is using the application as a digital tool to solve the task, to estimate the number of squares in different colours and to sort them accordingly. Moreover, several of the questions, prompts, and comments by Leo suggest that John carries out actions. Affordance is also predominantly due to the multimodal nature of interacting with the digital tool (cf. Roth, 2001). When it comes to the interaction amongst the children with respect to the digital tool, the excerpt above shows a constraining feature. Even though the application does not per se constrain interaction between the children, engaging with the digital tool by using a data mouse constrains interaction amongst the children as well as action by the other child, Jack. The person who steers the mouse is the one who actively engages with the digital tool(s). Constraining features are also related to the limitations of the digital tool per se. In many respects, the digital tool focuses on closed tasks and questions, leaving a scant space for problem solving. The dominant role of the adult in this case may also be seen as constraining the
interaction, making fewer opportunities for the child(ren) to engage freely with the digital tool. However, Leo’s efforts and interaction with the digital tool also intentionally focus on the mathematical ideas of sorting, number, and counting. Digital harmony and prolonging of the inherent didactics of the digital tool affords John’s process of appropriating these mathematical concepts.

In this short excerpt we observe that Leo is using explicit gestures, pointing and sliding, to complement his oral instructions and explanations (cf. Goldin-Meadow, 2009; Ladel & Kortenkamp, 2013). However, John’s gestures are of an implicit nature as his gestures are mediated by the use of the data mouse. John points to the various squares with the mouse cursor rather than pointing with his finger. In this sense the application implicitly affords the use of gestures. Moreover, the implicit gestures become actions John carries out to answer the questions and prompts by Leo.

**Excerpt 2: Further engagements with the tool**

The two girls, Ann and Judy, interacted with the same application as the boys, but in a separate room. The session was orchestrated by an adult, Kai. Kai judged that level 1 was quite easy for the girls and maybe not challenging enough. He thus made the decision to continue their interaction with the application using the part called “Falling toys” at level 3. In this way, Kai actively took part in increasing the mathematical learning opportunities on behalf of the children, by employing the affordances intrinsic in the applications. Kai’s action was closely related to the activity’s goal of letting the children through the use of the digital tool experience counting, the numerical relationship between numerals and the appurtenant number, as well as making sense of the table and the diagram. As seen in Figure 2, the children are now supposed to combine their sense-making of the table to the left, including the different numerals, and their sense-making of the diagram to the right. We also observe that the number span is increased from 0–5 till 0–10.

![Figure 2. An advanced sorting and counting activity (Author's translation in the text boxes)](http://web3.gyldendal.no/multi/1-4nettoppgaver/multi2a/kapittel3/oppgaveC/nivaa3)
Since the children are unable to read the text at the top (within the text box) and the text in the table (*leke* = toy, *antall* = number), Kai informs the children what they are supposed to do. Physically, both girls sit in front of a computer connected with a touchable screen which the girls use directly to solve the mathematical tasks. They tapped the falling toys with their fingers, and then the toys were removed into the corresponding columns. The activity is thus about realising what number the numerals in the table indicate, and to match that to the number of toys being stacked in the columns as they tap the falling toys. The dialogue lasted for about two minutes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Person</th>
<th>Words spoken</th>
<th>Non-verbal activity</th>
</tr>
</thead>
</table>
| 61  | Kai    | This is really difficult because now you see that there are quite big numbers *there*  
Do you know what these numerals mean? | Points at the numerals in the table |
| 62  | Judy   |              | Starts immediately to tap her finger on the toys as they fall from the top of the screen |
| 63  | Kai    | Yes, like that(…) Do you understand what to do here? | |
| 64  | Judy   | Mm           | |
| 65  | Kai    | Mm           | |
| 66  | Judy   | Six of *those* | Points at the column where the teddy bears are supposed to be put |
| 67  | Kai    | Ye::s(,) So you are familiar with such big numbers? (…) Now, Ann can continue  
One finger tap, like that | Judy has gotten three teddy bears, three airplanes and two bottles placed in correct columns  
Ann taps with her finger on the column where the planes are supposed to be put and a text box occurs on the screen |
| 68  | Judy   | One finger tap, Ann | |
| 69  | Kai    | One finger tap. Let’s see(,) Like *that*  
One finger tap on the toy | Removes the text box |
| 70  | Ann    |              | Taps the falling toy, but the toy is not removed to the column. It slides down out of the screen |
| 71  | Kai    | The next toy will work just fine(,) One tapping | |
| 72  | Ann    |              | Taps the toy once with her finger and the toy is removed to the corresponding column |
| 73  | Kai    | Great        | |
| 74  | Judy   | I just helped you | Judy starts tapping the falling toys |
| 75  | Kai    | Yes, but now it was- | |
| 76  | Ann    |              | Continues to tap the falling toys and the toys are stacked in the columns |

---


179
Kai (61) initiates this dialogue by telling the girls that this particular application is really difficult due to the big numbers included (potentially up to ten, but in this particular case eight is the largest number). However, based on the girls’ subsequent actions and utterances, the inclusion of relatively large numbers does not make the application difficult. They do not explicitly respond to Kai’s comment. Instead, Judy (62) starts to do what she is supposed to do with this application, to tap her finger on the falling toys in order for them to be stacked in the columns. Kai (63) realises that at least Judy seems to know what to do here, and he confirms that she acts according to the task. Judy (64) confirms that she knows what to do, and she makes her thinking explicit in (66) where she explains that they need six bottles to make the column(s) and the table correspond. Her gesture in this respect, pointing at the correct column, functions as an externalisation of her thinking. Her gesture in this case makes explanatory words superfluous (cf. Goldin-Meadow, 2009).

The next passage of the dialogue (67–76) concerns Ann’s apparent difficulty in mastering the finger tapping of the falling toys. She does not precisely hit the falling toys and taps her finger on the column where the planes are supposed to be put. Eventually, she masters it, after recommendations by both Kai and Judy, and gets positive feedback (73). Then Judy (74) starts to tap the falling toys, even though it is Ann’s turn. I interpret this as Judy showing her eagerness to interact with the tool. She also says that she wanted to help Ann do the necessary actions. This interaction is afforded due to the children’s engagement with a touchable screen, and would not have been possible in the boys’ case in excerpt 1. A touchable screen affords collaboration. Ann does not comment on Judy’s interventions, but Kai (75) makes it clear that it is currently Ann who is supposed to do the tapping. Ann does not make any oral statements, but her actions (76) indicate that she has made sense of the functionality of the application and she uses it as a tool to sort and stack the various toys.

Judy (77) then externalises her thinking by making explicit how she makes sense of the table within the application. They are to get six bottles, eight airplanes, and six teddy bears stacked in the columns. Kai (78) confirms that Judy is right before he makes the children aware that they constantly have to compare the number of toys they have so far stacked in the columns with the numbers in the table. Judy (79) then counts the number of bears by synchronising the tempo of her counting with nods of her head. The one-to-one correspondence as a fundamental aspect of counting and the cardinal aspect of the number concept is in this way made explicit. Judy’s gesture supports her oral statement (cf. Goldin-Meadow, 2009). The gesture and the voice thus mediate the same mathematical idea. Kai (80) elaborates on the situation by asking about the number of bottles stacked. While he asks the question Ann continuously taps the falling toys, making the number of
toys in each column equal. Ann (81) counts the number of bottles by moving her gaze (since she is neither nodding her head nor pointing with her finger), and she furthermore repeats the last number word reached. This indicates that Ann has made sense of the cardinal aspect of the number concept (cf. Ladel & Kortenkamp, 2013). Kai (82) then summarises his impressions from following the girls’ interaction, and he concludes that the girls are good at mastering the digital tool.

By changing the level of difficulty and the exact application for the girls to engage with, Kai takes advantage of the affordances offered by the tool, in order to challenge the children and create a learning activity in which both girls have opportunities to participate with their ideas and actions. The role of the adult is that of the more capable peer and thus crucial in order to develop the tool’s implicit learning opportunities. Constraints are faced in this excerpt too, as the application does not allow for more than one person at a time to interact and carry out actions. In spite of that, I interpret the girls’ interaction with the digital tool, showing eagerness and dedication, as indicating that they want to master the tool and deal with it accordingly.

Discussion

In this study I set out to come up with possible answers to the research question: *In what ways does use of digital tools in kindergarten give mathematical learning opportunities with respect to sorting and counting?* As we have seen from the analyses of the dialogues above, interaction and engagement with the web-based applications nurtured the children’s processes of appropriating the implicit mathematical ideas and concepts (cf. Moschkovich, 2004). The digital tools to engage with were carefully chosen by the adults in accordance with their mathematical learning goals. The adults aimed at letting the children use the tools to experience sorting and counting, and numerical relations between numerals and appurtenant number. From the analyses we see that the children were jointly involved in a process of establishing shared meanings and making sense of the mathematics by transforming their actions with the digital tool to make sorting and counting their own (Rogoff, 1995; Wertsch, 1998). As seen from the dialogues, the children demonstrate their sense-making of the issues of subitizing, one-to-one correspondence and cardinality (Fischer, 1992). They also show that they make sense of numerals and their numerical meaning. Moreover, the children’s opportunities to sort and count the squares and toys were afforded by their interaction with the digital tool and its multimodal nature (cf. Roth, 2001). The use of voice, use of gestures such as pointing and tapping, body movements such as nodding and manipulation of screen objects thus support the children’s externalisations of their mathematical thinking. These gestures thus played an important part in the persons’ interaction as complements to their utterances (cf. Goldin-Meadow, 2009; Ladel & Kortenkamp, 2013). These externalisations indicate that the children are participants in a process of appropriating the mathematical concepts of sorting and counting and thus the number concept.

Apparently, the digital tool carries both affordances and constraints (cf. David & Watson, 2008) with respect to the participants’ collaboration, in particular within the context of using the screen and mouse to engage with the digital tool. The applications engaged with offer several opportunities for interaction and action among the participants. The applications are about doing something with mathematical objects and toys, thus the affordances are related to counting and sorting squares and toys in accordance with given numerals. The children have to make sense of the screen in each case, with its inherent pictures, table, diagrams, and mathematical symbols. Moreover, the children have to interact with the digital tool in order to carry out the supposed actions. As argued above, the digital tool affords the children to become interested in the activity of moving and stacking coloured shapes on the screen and tapping falling toys. However, it is also evident that the digital tool, in the
way it is operated in this study, has limitations with respect to actively engaging both children at the same time. This is also due to the difference in equipment used. The boys engaged with a portable computer with a mouse. The mediation of actions by way of the mouse constrains collaboration between the boys. In the girls’ situation the touchable screen potentially affords collaboration even though this is not particularly taken advantage of. I thus argue that opportunities for mathematical learning were more afforded in the girls’ situation than the boys’ situation, since the touchable screen gave the girls more explicit possibilities for mathematical collaboration.

Dialogue is in both excerpts used as a medium of learning. The adults’ comments, questions, and prompts made their interaction with the children and the digital tools into learning activities. In both excerpts, the adults took a dominant role, particularly in excerpt 1. This domination of the interaction may constrain both the interaction between the child and the digital tool as well as interaction amongst the children. Nevertheless, as more capable peers, the adults orchestrated the interaction with the digital tools and dealt with the tools’ affordances and constraints (David & Watson, 2008). The affordances were taken advantage of to create opportunities for the children to appropriate the mathematical concepts implicitly present in the applications. The tools’ constraints reflected a didactical dissonance from the outset (cf. Vangsnes et al., 2012). However, this dissonance was transformed into greater harmony due to the multimodal adult–child interaction (cf. Goldin-Meadow, 2009; Radford, 2003; Roth, 2001).

There is thus no striking didactical dissonance emerging in the two excerpts that we have seen. Rather, I argue that didactical harmony occurs in these situations. The adults take advantage of the digital tool’s affordances in order to orchestrate mathematically meaningful learning activities on behalf of the children. These competent adults prolong the learning space of the digital tool. This result thus complements the argument of Vangsnes et al. (2012) in that didactical dissonance is possible to avoid when using digital tools designed to foster mathematical learning. Moreover, prolonging the digital tool’s learning space is possible when competent adults take advantage of the tool’s affordances.

Even though this study is limited to the analyses of two situations, it is evident that the adults play crucial roles in orchestrating these situations as mathematical learning opportunities. In each setting, the adult carries out actions, asks relevant questions, and comments on the children’s interaction with the tool(s). Through their questions and comments they seek to explicate the implicit mathematical concepts and ideas involved in the application(s). The digital tool’s mathematical affordances are in the kindergarten context heavily and wholly dependent on the competent adult and his/her situational judgements, along with the children’s interaction, the mathematical questions asked and mathematically clarifying comments made. More research is needed to further analyse the mathematical learning opportunities afforded when kindergarten children interact with digital tools.

This view of the process of appropriation is fruitful when studying children’s engagement with digital tools, since the research conducted deals with children participating in activities where they are indirectly exposed to mathematical ideas and concepts through the use of digital tools. To be specific, the children studied here are in their initial phase of using mathematical and digital tools. In order to participate actively, meaningfully, and critically, they need to know how to interpret pictures, tables, and diagrams, know how to operate the mouse and a touchable screen, and they need to know how to interpret graphs and mathematical symbols used within the web-based applications.
References


Guðmundsdóttir, G. B., & Hardersen, B. (2012). *Småbarns digitale univers. 0–6-åringers tilgang til og bruk av digitale enheter på fritiden*[Small children’s digital universe. 0–6 year-olds’ access to and use of digital units in their free time]. Oslo: Senter for IKT i utdanningen.


---

1 This project was funded by the programme LA2020 at the University of Agder. In this project I collaborated with two colleagues, Per Sigurd Hundeland and Ingevald Erfjord.

2 This article shares research issues with a Norwegian article: *Barns bruk av digitale verktøy i barnehagen: Muligheter for å gjøre seg matematiske erfaringer*, which will be published in the journal Nordic Studies in Mathematics Education. However, the Norwegian article has a different focus than what is the case here.

3 Transcription codes: () small break; (…) longer break; *italics* words associated with non-verbal activity; - sudden break; :: prolonged sound or letter; . end of sound; CAPS loud utterance.