Preface

This volume contains the papers presented at SIG20 Meeting: SIG20 Meeting on Computer Supported Inquiry Learning for The European Association for Research in Learning and Instruction held on August 17-19, 2014 in Malmö.

There were 23 submissions. Each submission was reviewed by at least 2, and on the average 2.0, program committee members. The committee decided to accept 19 papers. The program also includes 2 keynote talk and 2 ICT Demos.

Thanks to EARLI organization and the Fcaculty of Technology of Society at Malmö University for the supoprt.

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Malmö
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Development of Students’ Critical Thinking Skills through Argument Mapping with the Use of Rationale™ Software

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Abstract

To investigate whether argument mapping, with a use of Rationale™ software, cultivates students’ critical thinking skills, an experimental research was designed and implemented in Cyprus’ primary schools. Thirty 6th grade primary classes participated in the research for a period of nine months. Three groups of ten classes each were formed, of which two were the experimental groups and the third was the control group. The first experimental group worked in groups of three, with one computer for each group, on reasoning activities using Rationale™ software. The second experimental group worked on the same reasoning activities in the same way but using pencil and paper instead of any software. Students in the control group worked on reasoning activities using their Greek language textbooks, without any specific intervention in their learning process. A pre-test and a post-test were submitted to all students participated in the research in order to assess their reasoning and critical thinking skills. The comparison of pre-test and post-test means scores reveals that there is a statistically significant difference in, due to the performance of the students of the first and the second experimental group where the teaching intervention took place. The study findings are indicating that carefully designed argument mapping activities supported by argument visualization software, combined with systematic, conscious and organized quality practice within a cooperative and constructivist learning environment by educators specially trained in the theory and practice of critical thinking may promote the cultivation of students’ critical thinking skills.

Extended summary

Reasoning is a central component of critical thinking (Butchart, Forster, Gold, Bigelow, Korb & Oppy, 2009; Ennis, 1987; Fisher & Scriven, 1997; Kuhn, 1991; Moore & Parker, 2007; van Gelder, 2001) and an important social dexterity for the future active citizens of democratic societies since it is involved in all beliefs of individuals, in their judgments, in their conclusions and in the way they face their everyday problems (Kline, 1998; Kuhn, 1992). Many studies have shown that students are able to develop reasoning but often face difficulties associated with how they construct, organize and present their arguments (Andriessen, 2006; Bell, 2004; Erduran, Simon & Osborne, 2004; Felton & Kuhn, 2001; Jimenez, Rodriguez & Duschl, 2000; Kuhn, 1989, 1991, 1992; Kuhn & Udel, 2003; Sandoval, 2003; Suthers, 2003).

The typical format for the presentation of reasoning is prose (e.g. arguments found in newspapers, books or internet resources). Extracting the structure of the relationships in a reasoning as typically presented in prose, however, is very difficult (van Gelder, 2002). Van Gelder (2002) suggests argument maps as a way to develop and present arguments because they are more readable and comprehensible than prose. An argument map is a visual representation of an argument that immediately identifies claims, reasons and objections. Argument maps require less interpretation since all relationships are made completely explicit using simple visual conventions. They can be understood more easily via colours, shapes, arrows position in space, and other visual clues and they are well suited to the non-sequential structure of most arguments (van Gelder, 2003). Relevant research shows that the ability to construct argument diagrams improves students’ critical thinking skills (Harrell 2004,
2005; Twardy 2004; van Gelder, 2001, 2003). Despite their effectiveness, argument maps have never really been used as a practical tool for real reasoning or deliberation (van Gelder, 2002; Twardy, 2004). The main reason, among others, is that their creation with manual technologies (pen and paper or white boards) is both difficult and time consuming (van Gelder, 2002).

Using software specifically designed to support argument mapping such as Rationale™ (van Gelder, 2007), which helps students to create, organize and manage argument maps, one can now assemble argument maps easily and rapidly. This may overcome the limitations of manual technologies and help students to confront most of the difficulties faced when attempting to develop and support logical arguments (Bell, 2004; Clark & Sampson, 2006, 2008; Evagorou & Osborne, 2008; Twardy, 2004; Sandoval, 2003; Suthers, 2003; van Gelder, 2001, 2002, 2003). This particular software was chosen for this study because it is user friendly and as such appropriate to be used by primary school students.

To investigate whether argument mapping, with the use of Rationale™ software, cultivates students’ critical thinking skills, an experimental research was designed and implemented in seventeen Cyprus’ primary schools. Thirty 6th grade primary classes (N=481) participated in the research for a period of nine months. Three groups of ten classes each were formed, of which two were the experimental groups and the third was the control group. Critical Thinking Test (CTT) was submitted to all students participated in the research in order to assess their critical thinking skills before and after the instructional intervention. Test was designed, developed and validated by the researcher for the purposes of this study and based on the core critical thinking skills according to the American Philosophical Association (1990).

After the pre-test all teachers of the two experimental groups (20 teachers) received fifteen hours training in non-school time by the researcher for the implementation of the instructional intervention. Upon the completion of their training teachers were asked to implement the instructional intervention in their classrooms and work on reasoning activities. The first experimental group worked in groups of three, with each group using one computer, on reasoning activities (argument jigsaw, wrong argument map structure, construction of argument map, argument chess and debate) using Rationale™ software. The second experimental group worked on the same reasoning activities in the same way but using pencil and paper, instead of any software. All applied activities used by the first and the second experimental group were developed by the researcher and the teachers during their training for the purposes of this research. Students in the control group worked on reasoning activities using their Greek language textbooks, without any specific intervention in their learning process.

The data analysis revealed that the pre-test mean score of all students participated in the research was 8.56 whereas the mean score of the post-test was increased up to 10.14. The difference between the mean scores was statistically significant (t=-9.634, p=.000 for p<.05). This increase of the mean score was mainly due to the performance of the students of the first experimental group and the second experimental group where the instructional intervention for the cultivation of critical thinking skills took place. This conclusion is based on the evidence found by the comparison of pre-test and post-test means scores in both experimental groups. A statistically significant difference was found in the first experimental group mean scores (t = -13.181, p = .000
for p < .05) and in the second experimental group mean scores (t = -4.378, p = .000 for p < .05), with an increase of the mean scores for both groups.

The findings of the study contribute to existing knowledge on critical thinking by examining the effects of argument mapping on the cultivation of primary students’ critical thinking skills. The findings offer additional evidence in the line of work showing that carefully designed argument mapping activities using argument visualization software, combined with systematic, conscious and organized quality practice in a cooperative and constructivist learning environment by trained educators in critical thinking theory and practice may promote the cultivation of students’ critical thinking skills. Scaffolding students’ critical thinking skills using argument maps and argument visualization software might be a promising path in developing thinking citizens who will appreciate the value of intellectual discourse and will be competent to engage in it effectively.

References


Scaffolding citizen inquiry science learning through the nQuire toolkit
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Abstract
Citizen science is a popular paradigm of research collaboration between scientists and non-professional members of the public with the aim to contribute data to natural and physical science projects such as species identification. We have utilised this paradigm to scaffold online personal inquiry learning within informal settings. The nQuire Missions toolkit is a web platform to host the development and management of personal inquiry missions by young people combined with a sensor-based mobile application to support the collection of data on mobile phones. Scaffolding citizen inquiry science is a challenging task, as proposed missions should be personally meaningful, use recognised methods of data collection and analysis, and be valid and ethical. The concept, design and example science missions have been developed through a partnership with Sheffield University Technical College (UTC) where teachers and students acted as design informants. The result of the design exercise has been a specification for the nQuire Missions software and examples of missions which use the mobile phone to collect and share data.

1. Research objectives/hypotheses
The research objective of this paper is to present the design and evaluation of web-based and mobile tools that scaffold citizen inquiry science learning and in particular transformative and regulatory inquiry processes in informal settings. Transformative processes refer to core inquiry processes including the generation and testing of hypotheses, data collection and analysis, and reflective argumentation practices. Regulatory processes refer to the management of inquiry such as planning and progress tracking (van Joolingen et al., 2005). Drawing from our previous work on online personal inquiry learning (Anastopoulou et al., 2012), learners might become more engaged with the scientific process if they implement personally meaningful science investigations. Also, to support online personal inquiries, tools should provide functionality, flexibility and support when creating inquiries as well as a repository of exemplar inquiries to facilitate understanding of the inquiry design process (Quintana et al., 2004). Software application (app) projects (Newman et al., 2012) and web 2.0 technologies (Catlin-Groves, 2012) might comprise the means to attract the interest of young people in science. With 81% of UK teens owning a smartphone (eMarketer, 2014) and 85% of US youth using their phones to go online (Duggan & Smith, 2013), merging mobile phone use and citizen inquiry science might hold the potential to raise young people’s interest in inquiry learning.

2. Methods of data collection
We have partnered with students and staff from Sheffield UTC to design two tools for citizen inquiry science: the nQuire Missions website (www.nquire-it.org.uk) and the Sense-it app for Android mobile devices (see Google store). UTC staff proposed the design of a sensor-based mobile application for science inquiries. Sense-it gives access to sensors on phones and tablets, such as their accelerometer, light, sound, humidity sensors and allows users to capture, visualize, store and download log files from the sensors available on their mobile devices. A first prototype of the Sense-it mobile app was developed and a workshop with Sheffield students (Males=86, Females=10, aged 16-18) was implemented to evaluate the app and give students the opportunity to propose personal inquiries using it. Students downloaded the Sense-it app to their devices before the workshop. On the day, they were asked to explore the app’s affordances in groups (n=14) and complete two worksheets.
The first one required to evaluate the app by stating what students like/dislike about it and how they would improve it and the second one to write down two inquiries (i.e., title, aim and method of inquiry) that might be implemented using the app. Students’ responses were clustered in groups of relevant meaning and reduced into summary categories using thematic analysis (Kvale, 1996). Based on students’ suggestions, the design and functionality of the app was improved and some inquiries proposed by students were designed, selected by the researchers on the basis of practicality and broad reach. These inquiries are hosted in the nQuire Missions website which is linked to the Sense-it app and provides support for data visualisation, analysis and interpretation.

3. Data analysis/evidence

The analysis of students’ evaluation of the Sense-it app resulted in the following themes: accessibility obstacles including the complex information display (e.g., graphs and sensors were hard to understand), difficulty in navigation, need for simplicity when using the application, lack of attractiveness in colours, sensor icons design and fonts, satisfaction by sensors’ customization and the multimodal presentation of recording data (numbers and graphs), and productive use of mobile phones. Students’ proposed inquiries were grouped into the following categories: sound, light, acceleration and temperature. Some example inquiries are: What is the top speed of the lifts in the UK?, Does noise affect your concentration in lesson?, How bright does light need to be to wake you up?. Two of these inquiries were designed in the nQuire Missions website; Find the fastest lift in your area: Learners are asked to measure the speed of lifts in their area using the Sense-it app, upload their recordings to the website and compare it to other people to identify the fastest lift in their area. School noise map: This mission requires from school students to measure the level of noise in different places at their school using the Sense-it app and identify whether noise makes them feel stressed and annoyed. The aim of this mission is to make students aware of the effects of noise and propose measures to minimize it for better well-being.

4. Research Outcomes

The nQuire toolkit can support young people in inquiry sense-making and process management (Quintana et al., 2004). Visual conceptual organizers are used to represent the basic operations of science inquiry including, naming and describing the science mission, numbering its objectives, proving step-by-step guidelines on how to take part in the mission, and selecting the methods of data collection from a repertoire of available instruments such as the Sense-it app. Exemplar inquiry missions (see previous section) assist with the investigation of the underlying properties of inquiry structure. Post-processing algorithms and automatic chart creation scaffold the process of data analysis and interpretation. To support reflective processes and argumentation (Quintana et al., 2004), it provides links to popular social network sites (Facebook, Twitter) to invite ‘friends’ to join missions, an asynchronous chat channel to enable communication and discussion moderation by experts. The Sense-it app was designed to give access to phone sensors and support transformative inquiry processes (Joolingen et al., 2005) through data collection and visualization. To facilitate participation, the list of sensors required for each mission can be downloaded from the website and a graph on how data recordings relates to other people can be previewed.
5. Scientific or scholarly significance of the study or work and limitations

This work is significant for it embeds inquiry learning into citizen science projects to encourage youth civic participation, it facilitates the design of online personal inquiries by offering the nQuire toolkit, and it attempts to bring science closer to the life of young people through the use of their mobile devices. The proposed missions have not yet been evaluated with young people to assess whether they are engaging, raise and sustain interest in science and what their learning outcomes are. This limitation will be addressed within the next months though the design of a workshop with Sheffield students and analysis of data logs.

References


Effects of abstract and concrete simulation elements on learning outcomes, process, and on-task interest in elementary school inquiry-based science context

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1 Aim and research questions

In college context it has been found that learning with abstract representations produces predominantly better outcomes than learning with concrete representations (e.g. Kaminski, Sloutsky, & Heckler, 2008; McNeil & Fyfe, 2012), and that switching from one representation to the other during the learning can be even more productive (Goldstone & Son, 2005; McNeil & Fyfe, 2012).

The aim of the present study was to investigate the effects that concrete and abstract representations have on elementary school students’ learning in inquiry-based science learning context, because Kaminski et al. (2008) have proposed that the superiority of abstract representations would be universal, that is, the above kind of outcomes could be expected also among young learners, but their assumption has not been tested yet empirically.

The main research questions that guided the present study were:

1. “What kind of effect(s) the use of concrete and abstract representations have on upper-elementary school students’ learning outcomes, processes, and on-task interest in science?”

2. “Are the effects of concrete and abstract representations similar or different (universal vs. local) in elementary school context as compared to college context?”

2 Methods

2.1 Participants and design

The participants were 127 4th (n = 34) 5th (n = 25), and 6th (n = 68) grade students from Finland. The objective was to use a computer-simulation to discover the basics of series and parallel electric circuits (see Figure 1). The students had no previous formal education in electricity, and they worked in the following two simulation conditions:

In the concrete condition (CC; N = 63) simulation elements remained perceptually concrete (bulbs) throughout the experimentation (Figure 1, left picture).

In the fading condition (FC; N = 64) simulation elements switched from concrete (bulbs) to abstract (resistors) during the experimentation (Figure 1, right picture).
2.2 Procedure and materials

The empirical phase of the study took place over a one-week period.

Pre-test. In the first session, which took approximately one hour, the students completed a subject knowledge assessment questionnaire that was used to measure the initial level of students’ conceptual understanding of electric circuits. The questionnaire consisted of 29 circuit items, and it had a good reliability, $\alpha = .852$.

Allocation to conditions. Based on their pre-test scores, the students were placed randomly into the conditions.

Intervention (Learning phase). The actual intervention, when the students constructed and studied various circuits in the concrete or fading condition, took place in the schools’ computer suite. The students had 90 minutes to complete as many of the total of 9 circuit worksheets as possible. Students’ situational interest (i.e. on-task interest) was measured in four different phases of the intervention, and on each phase they were also asked to indicate their personal task difficulty.

Post-test. In order to compare the relative effectiveness of the learning conditions and assess the changes in students’ conceptual understanding of electrical circuits, the students completed the subject knowledge assessment questionnaire again one day after the intervention ($\alpha = .915$).

3 Results and discussion

3.1 Learning outcomes

According to a 2 x 3 repeated ANOVA, with condition as independent variable and grade level as a categorical control variable, the interaction effect between test phase and condition was not significant, F(1, 121) = 2.172, p = .143, meaning that, overall, the students gained approximately equal amount of knowledge in both conditions. However, a significant higher order interaction effect between grade level, condition and test phase suggested that there were differences between the conditions on a specific grade level, F(2, 121) = 3.301, p = .040. In order to examine this effect more closely, a repeated ANOVA was run independently for each grade level. This revealed a significant interaction effect between test phase and condition among 5th graders, F(1, 23) = 6.864, p=.015, but not among 4th and 6th graders (p > .05), suggesting that the learning gains were significantly different between the conditions among 5th graders. As shown in Figure 2, there was an interesting developmental pattern that differed between the conditions. Among 4th graders, the slopes that illustrate the magnitude of the learning were virtually identical in both conditions, and the overall ratio of correct post-test answers was relatively low, suggesting that both conditions were relatively ineffective in supporting 4th graders’ conceptual understanding of electric circuits. Among 5th graders, the learning curve was notably steeper in CC as compared to FC, suggesting that at this age the students started benefitting from learning with constantly concrete representations; in FC there was no change as compared to 4th graders. Among 6th graders, the differences that were found among the 5th graders disappeared. As the overall proportion of correct post-test answers was relatively high in both conditions, it can be argued that 6th graders learned the basic principles of electric circuits reasonably
well independent of the learning condition, and this was the first age group that was able to cope properly with the demands of learning with abstract simulation elements.

3.2 Learning process

Three different indicators were used to assess the fluency of the students’ inquiry process: 1) Learning time, 2) Self-reported on-task difficulty, and 3) Self-reported on-task interest. According to a 2 x 3 factorial ANOVA, the students in CC spend significantly less time on learning as compared to those in FC, F (1, 121) = 6.230, p = .014. This could indicate that the inclusion of abstract elements made the inquiry process more difficult in FC than in CC. While no statistical differences were found in the perceived task difficulty between the conditions, F (1, 98) = 0.300, p = .585, learning with constantly concrete elements was perceived as more engaging with students in CC reported on average higher on-task interest than the student’s in FC, F (1, 98) = 5.449, p = .022. This could be a significant finding as higher level of engagement might contribute to students’ long term interest towards science learning (Hidi & Renninger, 2006).

4 Conclusions

Earlier studies have found that in college context learning that involves abstract representations tends to promote students’ understanding more effectively than learning with constantly concrete elements, and Kaminski et al. (2008) have proposed that these outcomes would extend to elementary level as well. The outcomes of the present study, which provide the first empirical test for Kaminski’s assumption, found that in elementary school context learning with constantly concrete representations resulted in either equal or better learning outcomes than learning that involved both concrete and abstract representations, it reduced learning time, and was perceived by students as more engaging learning environment. Taken together, the present and
earlier findings suggest, in contrast to Kaminski’s claim, important differences between college and elementary school students in how concrete and abstract representations affect their conceptual understanding in science; the present findings suggest that constantly concrete representations might be more suitable means to pursuing inquiry-based science activities in elementary school context than including abstract representations.

5 References:


How digital augmentation design shapes students’ history inquiry
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Digital augmentation via mobile technologies has the potential to facilitate new forms of history learning. Exploring the past through digitally augmented environments in which digital stimuli are linked to the physical surroundings exploits ‘physicality in interaction’ (Price & Rogers, 2004, p. 138) and situates learning in relevant physical contexts. It is not clear however, how different types of digital representational stimuli shape student interaction as a result of their content and form, and the implications of this for students’ historical inquiry when it occurs in situ. This paper aims to better understand the effectiveness of different types of representational stimuli in prompting active historical inquiry that brings past experiences ‘closer’. Drawing on a multimodal perspective, this question is explored through an analysis of 9-10 year old students’ interactions as they explored the WWII history of their local Common using mobile technologies. Analysis focused on 18 episodes involving students accessing one of three types of digital stimuli that were ‘tagged’ to their physical surroundings. Engagement with each of these stimuli was found to shape students’ action and interaction as a result of their content and mode of their presentation. Considering these specific instances enabled the properties of different digital stimuli more generally to be mapped to potential responses in this kind of learning task. This is especially useful for informing designers of digitally augmented learning experiences, particularly those intending to facilitate students’ active exploration of the past through their present physical environment.

Introduction

Mobile technologies offer new opportunities for providing information than is normally available in the immediate physical environment (Rogers et al., 2002; Vogel et al., 2010). Recognising that different modes of information have different potentials and constraints (Kress, 2010) leads us to ask whether certain types of digital stimuli are more suited than others to supporting particular types of learning (Jewitt, 2013; Price et al., 2008). Analysing action and interaction as it unfolds in response to different types of digital stimuli can help us to identify which stimuli, in terms of mode and content, are the ‘best fit’ in a context of learning (Jewitt, 2013, p. 255). Some studies have considered how different modal resources, including digital stimuli, shape student engagement and interaction (Lemke, 1998; Bezemer & Kress, 2008; Jewitt, 2008). In research on learning activities involving digital augmentation via mobile technologies, there have been interesting, though less systematic, findings as to how different types of digital stimuli shape student action and interaction (e.g. Rogers et al., 2004). There is a lack of research however, that explicitly focuses on how different forms of digital stimuli shape action, interaction and reflection during a digitally augmented learning activity. Furthermore, this question has not been considered in relation to history learning that is designed to bring the past ‘closer’ to students by linking the physical environment to relevant historical stimuli. To investigate this, an analysis of 9-10 year old students’ use of mobile technologies to explore WWII history on their local Common was conducted.
Study design

32 students from a London primary school, aged 9-10 years, took part in an activity designed to engage them in an exploration of the experiences and events of WWII that had a particular association with their local Common. The design of the activity was based around the mobile application *Evernote*, made available through iPads, which allows the creation of ‘notes’ containing written, visual and/or audio stimuli tagged to physical locations. Fourteen ‘notes’ about WWII were constructed and positioned on a map of Clapham Common. The ‘notes’ were a mixture of stimuli that related to the WWII experiences of individuals living near to the Common. Each ‘note’ also contained prompts encouraging students to actively compare the past and present experiences of the Common, and sometimes to create their own content by taking a photograph or making an audio recording. Students worked in pairs and after a five-minute interactive demonstration of the app, each pair explored the Common for 25-30 minutes accessing and responding to ‘notes’. A researcher accompanied each pair capturing the exploration on video with a handheld camera, helping with any technical difficulties, and encouraging conversations to stimulate students’ engagement with the task.

Analysis was conducted on videos of the 16 student pairs. A multimodal transcription was used to record different modes of interaction including movement, body action, interaction with the iPad and speech. In order to compare the influence of different types of digital stimuli on prompting active historical inquiry that makes links between the past and the present, episodes of activity were identified that showed students responding to examples of three types of digital stimuli: *(i)* a sound clip of soldiers marching (6 episodes); *(ii)* a photographic image of civilians sleeping in a deep shelter under the Common (figure 1; 6 episodes); *(iii)* a letter written by the Reverend after the bombing of the church on the Common (figure 2; 6 episodes).

Figure 1. A photographic image of civilians sleeping in a deep shelter under the Common.
Findings

Analysis shows that students’ engagement with each of the stimuli above shaped the action and interaction that followed in particular ways. Responses differed in their length, character and intensity. For example, when students engaged with the written stimulus (the Reverend’s Letter), the majority of this time was focused on reading the letter out loud, rather than reflecting on the experience it described or its relationship to the present physical surroundings. On the other hand, when students were engaging with the visual stimulus (the photograph of people sleeping in the deep shelter), only a small proportion of this time was spent looking at the photograph and the majority was invested in reflecting on the past and re-imagining the present environment. This suggests that noted differences in the way that images and writing are organized and comprehended (Price et al., 2008; Kress & van Leeuwen, 1996) impact on how they are responded to when they are used to support history learning that occurs in situ.

Students also responded differently through their physical action and the extent to which the current physical environment was foregrounded in their response. For example, the audio stimulus of soldiers marching encouraged responses involving the students’ own dramatic physical movement around the Common, while when responding to the visual and written stimuli, students were more likely to remain still and close to the iPad, engaging with the Common via gaze and gesture rather than grosser forms of movement. Audio stimuli have been found to be useful in directing users’ attention to occurrences outside of their vision (Brewster, 2002). Audio also offers alternative ways of thinking about events through sound, which can convey concepts of activity and movement in particular ways. In the context of in situ history
learning, audio stimuli encouraged learners to engage with such material through enactment, illustrating how different modes of stimuli can serve important functions in interaction.

This analysis of interaction shows the differential extent to which different representational stimuli facilitated linking between the past and the present, and the type of conceptual relationship that the students constructed between the history of the Common and their present experiences of the site.

**Implications**

Considering the specific instances of student interaction presented in this paper enables the properties of different digital stimuli to be mapped to potential responses in this kind of learning task. This builds on work examining the potentials and constraints of different types of stimuli, to elaborate our understanding of the role of digital augmentation in supporting in situ history learning. It is also a useful tool for designers of digitally augmented learning experiences, particularly those intending to facilitate students’ active exploration of the past through their present physical environment.

**References**


Learning Trajectories for Ecosystem Ideas: Collaborative Support for Individual Understanding

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Abstract

In technology-rich inquiry learning environments, students’ paths to understanding systems may be multi-dimensional and be influenced by social and material factors in the learning environment. We trace one student’s learning trajectory for understanding photosynthesis in a technology-rich environment. To understand how what happened in the classroom contributed to this student’s conceptual growth, we examined video data and students’ artifacts. This provides a coordinated account of learning at both group and individual levels as we seek to understand the relationship between group activities and individual conceptual change.

Introduction

Systems thinking has been recognized as a key aspect of science literacy, but are challenging for learners to understand (NGSS, 2013; Hmelo-Silver, Marathe, & Liu, 2007). Technology rich environments show promise in helping students develop this understanding (Lee, Linn, Varma, & Liu, 2010). In such environments, students’ paths to understanding systems may be multi-dimensional and be influenced by social and material factors in the learning environment. Eberbach and her colleagues (2012) compared middle school students’ drawings at four time points to better understand their learning trajectories. However, they didn’t examine what happened between the drawing assessments.

Research Question

The research question guiding this study is how students develop their understanding of key ecosystem concepts. We accomplish this through a case study of how one student, Wendy, developed her understanding of one ecosystem concept, photosynthesis, after studying in a computer-supported inquiry learning environment (CSIL). We examine her understanding along the three dimensions described in Eberbach, et al (2012). We focus on photosynthesis as it is particularly a challenging and important ecosystem process (Ozay & Oztas, 2003).

Method

This study is part of a larger design-based research program that examined how the Structure-Behavior-Function (SBF) conceptual representation can be used to promote systems thinking. The study context was a six-week enactment of a curriculum unit organized around the problem of fish suddenly dying in a local pond. Working in small groups, students engaged in an inquiry through evaluation of different forms of scientific data, simulations, and the creation and revision of models using the Ecological Modeling Toolkit (EMT; Goel et al., 2013; Figure 1). The macro simulation (Figure 2) facilitated students’ exploration of relationships between sunlight, nutrient, algae.
growth, and fish population, which provided opportunities to explore the mechanism of photosynthesis. Students had access to a function-oriented hypermedia to help understand the simulation (Liu & Hmelo-Silver, 2009).

Data Sources
Data sources were video and student artifacts. These artifacts included pre and posttests tasks to draw a model of an aquarium and two other drawing tasks in which students were asked to design an aquarium (i.e. AA1 and AA2), both of which were assessed during the curriculum enactment. We choose Wendy as our case because she progressed well along the three systems levels, macro-micro, biotic-abiotic, and structure-behavior-function (Table 1), across four assessments (Figure 3). Closely scrutinizing her assessments and the video provided insights beyond the quantitative coding from Eberbach et al. (2012).

The goal of the video analysis was to create a coordinated account of Wendy’s learning trajectory, which examines how the group constructed understandings with the assistance of technological tools and how Wendy individually took up these understandings.

Results
Wendy incorporated limiting factors in AA1, integrated oxygen producers (i.e. algae) into AA2, and had an energy-driven perspective at the posttest (See Figure 4). Mapping her achievements onto the three understanding dimensions provided more insights about how her learning trajectory unfolded. In AA1, her integration of oxygen and having fish and oxygen connected showed that her understanding had reached the highest levels of Macro-Micro, and Abiotic-Biotic scores. In her AA2, she incorporated algae, as the oxygen provider, and had fish, oxygen and algae connected. Her connections were organized by the circulation of oxygen: starting from the producer, algae, and ending by the recipient: fish. This enabled her to reach the highest Structure-Behavior-Function level. At the posttest, Wendy added a sun, which showed her understanding of energy flow. Wendy improved her level of understanding by incorporating micro, abiotic, but important, components to her drawings. Her understandings of ecosystem concepts progressed from one ecosystem level (i.e. fish and oxygen) to a larger one (i.e. oxygen circulation) and reached the highest level: energy flow. This is hard and seldom achieved by students (Eilam, 2012). Wendy achieved this by constructing understandings with her group mates together in a CSIL environment. Although she was a quiet student, she made her contributions to the group product by operating the computer, writing down her group mates’ discussions and demonstrating her engagement through agreements or disagreements. In Table 2, we trace how activities in the classroom may have influence Wendy’s progress along her learning trajectory throughout the curriculum.

Significance and Future Direction
These result suggested that the technological tools and social mediation were critical for Wendy to achieve a positive learning trajectory. The CSIL environment supported Wendy’s learning trajectory in several ways. The simulation engaged students’ exploration of scientific concepts and provided opportunities for students to make their
thinking visible and open for discussion. EMT afforded students to articulate their knowledge and also provided a focus for intersubjective meaning making. Wendy attended to these activities actively.

This study is a start of exploring student activities in computer-supported inquiry learning environments. Our goal was to have a domain specific instruction that shows how students learn as well as what they learn (Cobb & Gravemeijer, 2008). Here, we provided an account of how one student came to understand key ideas related to photosynthesis while engaging in CSIL. In the future, we need to generate more of these accounts as a step towards understanding these complex learning trajectories.

| Table 1 |
| Scoring Criteria for Student Drawings (Eberbach et al., 2012) |
| --- | --- | --- |
| **Level 1** | **Level 2** | **Level 3** |
| Macro/Micro (MM; e.g., fish, plants/oxygen, bacteria) | Identifies only macro structures or processes | Identifies both macro and micro structures or processes | Identifies relationship(s) between macro and micro structures or processes |
| Abiotic/Biotic (AB; e.g., fish, plants/ammonia, sun) | Identifies only biotic structures | Identifies both biotic and abiotic structures | Identifies relationship(s) between biotic and abiotic structures |
| SBF (e.g., starfish eats the clams) | Identifies structures without connecting to behaviors or functions | Identifies structures in relation to behaviors or functions | Identifies structures in relation to behaviors and functions |

*Figure 1. The EMT Modeling Tool*  
*Figure 2. The Macro Simulation*
Figure 4. Wendy’s four assessments: top left: pre-test, top-right: AA1, bottom-left: AA2, bottom-right: posttest
Table 2

Summary of data: Reciprocal influences between Wendy and group as reflected in artifacts

<table>
<thead>
<tr>
<th>Pre-test to AA1</th>
<th>Technological Tools Used</th>
<th>Artifacts</th>
<th>Group activities</th>
<th>Group Discoveries</th>
<th>Wendy’s Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMT &amp; Scientific Data:</td>
<td>W*: evaluating scientific data: “Fish died of oxygen depletion by evaluating scientific data”</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

G*: EMT Model: Oxygen and fish are connected with the relationship of “fish need oxygen to live; lack of oxygen might have killed the fish.”

Updating the EMT model

1. One group member, Kate suggested adding oxygen to the model;
2. Another group member: Kyle suggested making connections between fish and oxygen.

Adding components to the model

AA1 to AA2

Netlogo simulations

W: worksheet: “Algae absorbs CO₂”

Exploring the interactive relationship among the number of fish, algae, oxygen and CO₂ manipulating the simulation

1. Fewer amount of algae would lead fish die of too much CO₂. Increasing the amount of algae would lead less CO₂. A conclusion was made: algae absorbs CO₂.

Setting up variables for the simulation; observing results from simulation runs; showing agreements

EMT

G: EMT model: having fish, oxygen and algae connected with the relationship: lacking of oxygen would kill the fish; lack of algae would lead to less oxygen.

Updating EMT model

1. Adding algae and photosynthesis and respiration into the EMT model, “because they are something needed for fish to live”.
2. Having a connection between algae, oxygen and photosynthesis with the relationship of algae photosynthesized to create

Adding notes, component and relationship to the EMT model.
3. By thinking of the overarching question: what killed the fish, one group member, Kyle thought they would connect fish with other components:

<table>
<thead>
<tr>
<th>AA2 to posttest</th>
<th>Simulation</th>
<th>Exploring the interactive relationships among sunlight, algae by manipulating variables from the simulation</th>
<th>With the remind from the classroom teacher, Kyle found as sunlight gets stronger, the amount algae gets higher, and fish population gets less.</th>
<th>Wendy was helping setting up variables (i.e. strength of sunlight: high; amount of algae: high).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom lecture</td>
<td>W: lecture notes: “the cell captured energy from sunlight to make its own food”</td>
<td>Classroom discussions</td>
<td>1. Sunlight is the major energy source. 2. Energy chain: plants take energy from the sun, and transfer the energy to animals.</td>
<td>Wendy attended to the lecture</td>
</tr>
<tr>
<td>Hypermedia</td>
<td>W: lecture notes: “the sun is the main source of energy”; “when there is more sunlight, producers photosynthesize more”.</td>
<td>Collaboratively study the hypermedia</td>
<td>1. Living things need oxygen, and chemical energy. 2. The sun is the main source of energy.</td>
<td>Wendy was writing down what her group mate read from the hypermedia</td>
</tr>
</tbody>
</table>

Notes: *W = Wendy. G = group.*
Reference
Supporting Inquiry Learning: A Meta-Analysis

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Abstract
Several studies found that inquiry learning is an effective way of learning when trying to discover domain knowledge and acquire inquiry skills. Inquiry learning has even proven to be more effective than direct instruction and other instructional approaches as long as the students are supported adequately. A question that raises immediately is ‘what type of support is adequate’ and ‘for whom’? This question is difficult to answer as most previous research has only focused on one type of support and one type of learner. This meta-analysis therefore synthesized the results of 72 studies to compare the effectiveness of different types of support for different age categories. Results showed facilitative effects of inquiry learning support in general on learning activities (\(d = .71\)), performance success (\(d = .66\)), and learning outcomes (\(d = .46\)). Type of support moderated the effects on performance success, but not on the other two outcome measures. Differential effects of support were found on learning activities, but the relatively low number of studies leaves it unclear whether these differences were due to the learners’ age.

Introduction
Inquiry learning is a process by which learners try to discover underlying principles and causal relationships of a domain (often science related) via self-regulated investigations. Performing these investigations calls upon a range of scientific reasoning skills that require students to be able to formulate hypotheses, test their hypotheses by conducting experiments and/or making observations, and interpret the outcomes to evaluate their initial hypotheses. In case these skills are performed as part of a more comprehensive inquiry project, students will also need to regulate their learning by planning and monitoring their investigations (de Jong, 2006). All of these activities ask for active participations from students, and it is therefore no surprise that learners of all ages often have difficulties with inquiry learning (e.g., de Jong & van Joolingen, 1998; Klahr, Dunbar, & Fay, 1993; Zimmerman, 2007).

In reaction to these findings several studies suggested offering inquiry support to help students overcome the problems they might experience during inquiry learning. These studies were synthesized in several recent meta-analyses that compared (un)supported inquiry learning with other instructional approaches. Alfieri, Brooks, Aldrich, and Tenenbaum (2011) found evidence that students do benefit more from guided inquiry learning than from unguided inquiry learning; other meta-analyses also highlighted the importance of guiding students during the inquiry (Furtak, Seidel, Iverson, & Briggs, 2012; Minner, Levy, & Century, 2010). Knowing that students benefit from inquiry support in general, a question that immediately raises is ‘what kind of support is adequate for which types of learners?’ Answering this question is difficult as previous research has almost exclusively focussed on one type of support and one type of learner. Therefore, a meta-analysis including such studies was conducted to examine which types of support are effective, and for whom.

Initial evidence for a differential effect of inquiry learning support comes from a research synthesis by Zimmerman (2007). She summarized a vast body of research on the development of scientific reasoning skills by
stating that “children are far more competent than first suspected, and likewise, adults are less so” (p. 213). Still, considerable variability in performance across age groups remains to exist, in particular with regard to inference and experimentation strategies. These differences intuitively suggest that younger learners require more or more specific support than older learners who supposedly are, or should be, more proficient in scientific reasoning. In order to capture these differences and identify their ramifications for support, the present meta-analysis focused on students in primary, secondary, and higher education and zoomed in at the differential effects of various types of support on children (5-12 years), teenagers (12-15 years) and adolescents (15-22 years).

In the sections that follow, a short overview will be given regarding the key developmental differences among these three age groups on learner characteristics related to successful inquiry learning. Followed by a framework to classify existing types of inquiry support, and relate support categories to the needs of children, teenagers, and adolescents to predict which types of support are (most) appropriate for which types of learners. These hypotheses were then tested in the meta-analysis, which is reported in the second part of this paper.

**Developmental differences in scientific reasoning**

Scientific reasoning is defined as the application of scientific inquiry methods to reasoning situations (Kuhn & Franklin, 2006). A large share of the research on scientific reasoning has focused on the cognitive processes involved in performing these methods through hypothesis generation, experimentation, and evidence evaluation. A well-known and respected model describing the cognitive processes underlying scientific reasoning is the Scientific Discovery as Dual Search (SDDS) framework of Klahr and Dunbar (1988). According to this model, scientific discovery can be conceived of as a dual search process that takes place in two related problem-solving spaces, namely the hypothesis space and the experiment space. Searches in the hypothesis space involve generating new hypotheses based on knowledge about a topic or domain; this knowledge can either be based on prior knowledge or inferred from data obtained through experimentation. Searches in the experiment space involve designing experiments, predicting the outcome of those experiments and running and interpreting the data, all to produce interpretable results. Searches in the two spaces are mediated by the evidence evaluation process. During this process the fit between theory and evidence is evaluated to guide further research in the hypothesis and experimental spaces (Kuhn, 1989; Kuhn, GarciaMila, Zohar, & Andersen, 1995; Kuhn & Pearsall, 2000).

*Hypothesis generation*

The ability to formulate hypotheses is not present until elementary school age the earliest (Piekny & Maehler, 2013). From that age onward, children, teenagers, and adolescents all tend to begin their inquiry by focusing on hypotheses consistent with prior beliefs—but differ in their attempts to generate subsequent hypotheses. Children tend to keep generating plausible hypotheses and often get stuck focusing on a single hypothesis, while older learners more often generate implausible hypotheses and are more likely to consider multiple hypotheses. Still, even adolescents spontaneously generate very few hypotheses, and confuse hypotheses and predictions (Njoo & de Jong, 1993). It thus seems that inducing new or alternative hypotheses from data remains difficult across age groups (Klahr et al., 1993).
Experimentation

The ability to design experiments suitable for generating or testing hypothesis has proven to be difficult across ages and is often investigated by testing participants’ ability to apply the Control-of-Variables Strategy (CVS). CVS is a method for designing unconfounded experiments. Learners who use the CVS correctly will create experiments in which a single contrast is made between experimental conditions, in other words they will only change one variable while keeping the other variables constant. In this way learners are able to distinguish between confounded and unconfounded experiments and make appropriate causal inferences from the outcomes of the unconfounded experiments (Chen & Klahr, 1999).

Piekny, Grube, and Maehler (2013) found that children aged four and five year are not yet able to distinguish between testing hypothesis and generating an effect, but a notable increase in correct responses was observed between the age of five and six years. They also suggested that conducting experiments to test hypotheses in the sense of scientific reasoning may be far too demanding for pre-schoolers, and that the age of between five and six may be a sensitive phase for the development of these abilities. Sodian et al. (1991) also found that young elementary school children (first and second grade; 6-9 years) can distinguish between testing hypotheses and generating an effect. Koerber et al. (2011) found a significant improvement in experimentation strategies between second and fourth grade students: most second graders responded on the level of naïve conceptions, while most fourth graders responded on the level of intermediate conceptions. Basic competence in carrying out investigations of the relationship between variables that clearly covary can be acquired by many pupils by the age of 10 (Kanari & Millar, 2004), but with the right support children in first grade (age range 6-7 years old) are already able to learn how to carry out sound investigations (Chen & Klahr, 1999; Varma, 2014). With age, children increasingly improved their ability to transfer the learned CVS strategy to new domains (Chen & Klahr, 1999).

Klahr et al. (1993) found differences in experimentation strategies between children and adults. Children were more likely to conduct several experiments testing variables that were already understood, whereas adults would move on to exploring variables they did not understand that well. When younger children were given a task in which they had to impose multiple constraints on hypotheses and experimental design, they did not conduct appropriate experiments; instead their comparisons were often informative. In a study by Kanari and Millar (2004) it was found that children compared to teenagers were more likely to repeat measurements when exploring non-causal variables. Sodian et al. (1991) argued, however, that in studies where both hypotheses and experimental choices are highly constrained young children are able to select appropriate experiments.

Evidence evaluation

This scientific reasoning process involves the coordination of theory and evidence, which should lead to informed decisions on whether and how hypotheses should be accepted, rejected, or revised and further examined. To test the ability to evaluate evidence, learners often have to make inferences about causal relationships between variables showing different patterns of covariation (Piekny et al., 2013). Kuhn et al. (1988) examined the development of evidence evaluation for children, teenagers, and older learners, and found a developmental trend in that the older participants were more likely to make evidence-based responses. Both children and adults often incorrectly (and based on prior beliefs) interpreted a variable as causal when it actually was not, but adults did make more valid
interferences than children because they used a more valid experimentation strategy (Zimmerman, 2007). Furthermore, children more than adolescents or adults, tend to neglect or distort data when covariation evidence contradicts their prior beliefs or knowledge (Amsel & Brock, 1996). Valanides Papageorgiou, and Angeli (2014) found that sixth graders experience serious difficulties when coordinating theory with evidence, and that these difficulties were directly associated with the children’s inability to take full advantage of the data from both positive and negative experiments.

The ability to evaluate perfect covariation and non-covariation evidence develops during the preschool and early primary school years (Koerber et al., 2011; Piekny & Maehler, 2013). Preschool children at four years of age can already correctly interpret perfect covariation data as evidence supporting a causal hypothesis, and this ability improves significantly between the ages of four and five (Koerber, Sodaïn, Thoërmer, & Nett, 2005; Piekny et al., 2013). Between the age of four and five most progress is made in the ability to interpret imperfect covariation.

The ability to interpret noncovariation seems to be comparatively more demanding (Inhelder & Piaget, 1958; Koslowski, 2008; Kuhn & Phelps, 1982). It is therefore no surprise that this skill does not seem to be well developed yet at the age four and five (Koerber et al., 2005; Piekny et al., 2013), nevertheless 5-year olds could be prompted to overcome the difficulty of interpreting noncovariation evidence in the study by Koerber et al. Also, Piekny et al. (2013) found a clear increase in this ability between the age of four and six. Piekny and Maehler (2013) further suggested that evidence-evaluation skills, especially dealing with ambiguous data, might be a precursor for the understanding of experimentation and for hypothesis generation.

Typology of inquiry learning support
Children, teenagers, and adolescents differ in their ability to generate hypotheses, design and conduct experiments, and evaluate evidence, with older learners often showing more complex scientific inquiry compared to younger learners (Kuhn, 1997; Quintana et al., 2004). That being said, inquiry skills do develop from an early age (Piekny et al., 2013) and young learners can benefit greatly from inquiry learning support (e.g., Klahr & Nigam, 2004; Varma, 2014). But the same could be said regarding older learners who, due to their higher levels of proficiency, can be assumed to benefit from different types of support.

As a first step in investigating whether a differential effect of inquiry learning support indeed exists, this meta-analysis defined ‘support’ as any form of guidance offered before and/or during the inquiry learning process that aims to simplify, provide a view on, elicit, supplant, or prescribe the scientific reasoning skills involved. As both the term support and its definition are rather broad, some further specification seems appropriate. In previous writings, support has often been classified in terms of the inquiry skills it refers to. De Jong (2006), for example, organized various types of support according to the phases of the inquiry cycle, and Lazonder (2014) did the same for the three core scientific reasoning processes. A more coarse-grained distinction was proposed by Reid, Zhang, and Chen (2003), who made a distinction between interpretative support that helps learners understand important domain concepts, experimentation support for guiding learners in designing and conducting experiments, and reflective support that assists learners in looking back on their inquiry and the knowledge acquired. A similar classification was proposed by Quintana et al. (2004) who presented a series of scaffolding principles and guidelines to support ‘sense making’, ‘process management’, and ‘articulation and reflection’.
Even though the above classifications are generally acknowledged and frequently cited in the research literature, they offer too little guidance to identify and predict possible differences in support effectiveness based on the learners’ age. A potentially more fruitful typology was proposed by de Jong and Lazonder (2014) who organized their support framework according to the (increasing) specificity of the support students need to successfully perform their inquiry. A slightly adapted version of their typology was used in the present meta-analysis; a short description of its defining characteristics can be found in Table 1.

<table>
<thead>
<tr>
<th>Type of support</th>
<th>Basic idea</th>
<th>Intended audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process constraints</td>
<td>Restrict the comprehensiveness of the learning task</td>
<td>Learners who are able to perform and regulate the basic inquiry process, but still lack the experience to do so under more demanding circumstances</td>
</tr>
<tr>
<td>Status overviews</td>
<td>Make task progress or learning visible</td>
<td>Learners who are able to perform the basic inquiry process, but lack the skills to plan and keep track of their learning trajectory</td>
</tr>
<tr>
<td>Prompts</td>
<td>Remind to perform an action</td>
<td>Learners who are able to perform an action but may not do so on their own initiative</td>
</tr>
<tr>
<td>Heuristics</td>
<td>Remind to perform an action and suggest how to perform that action</td>
<td>Learners who do not know exactly when and how an action should be performed</td>
</tr>
<tr>
<td>Scaffolds</td>
<td>Explain or take over the more demanding parts of an action</td>
<td>Learners who do not have the proficiency to perform an action themselves or cannot perform the action from memory</td>
</tr>
<tr>
<td>Explanations</td>
<td>Specify exactly how to perform an action</td>
<td>Learners who are (largely) incognizant of the action and how it should be performed</td>
</tr>
</tbody>
</table>

*Note.* Based on de Jong and Lazonder (2014).

**Research questions and hypotheses**

This meta-analysis aimed to answer three questions: (1) what is the overall effectiveness of inquiry learning support on learning activities, performance, and learning outcomes, (2) does this effectiveness depend on the type of support, and (3) does the effectiveness of different types of support depend on the learner’s age. As Alfieri et al. (2011) reported positive effects of inquiry learning support, the present meta-analysis was expected to replicate this outcome in a more stringent comparison within the domains of math and science. However, as previous research also yielded differential effects of the support on student learning (e.g., Morgan & Brooks, 2012), the overall positive effect was expected to differ as a function of the type of support, with larger effect sizes being associated with more specific types of support. Still, specific supports such as scaffolds or explanations might be comparatively more effective for younger learners who experience more difficulties during an inquiry than older learners, who in turn might benefit more from less specific types of support such as process constraints.
Method

Literature search

Studies investigating support in inquiry learning were identified through a search of reference databases and a perusal of relevant conference proceedings. First, the databases of ERIC, PsycINFO, and Web of Science were consulted in January 2014. All searches were limited to the past two decades (published in the period 1993-2013). Searches were conducted with the following keywords: ["inquiry learning" OR "discovery learning" OR "control of variables"") AND ("students" OR "support" OR "instruction"], ["scaffold*" AND "inquiry"], ["scientific thinking" OR "scientific reasoning"] AND ("learning" OR "instruction")]. The Web of Science search limited by SSCI and CPI-SSH citation indexes only resulted in 738 hits. The search in ERIC and PsycINFO - additionally limited by [AB abstract] resulted in 774 and 589 hits. By comparing the total of 2101 hits, 524 duplicates were found. Exclusion of those duplicates resulted in a total of 1577 unique hits. In addition searching through the online conference proceedings for studies concerning support in inquiry learning of the EARLI, NARST and AERA resulted in an additional 89 hits (52 available and unique hits). Conference papers were collected online (29) or requested via the author (63 requested, 31 responses, 27 papers received), response rate 49.21%. Conference papers that were later published in article form were scanned for duplicates with the search results from the databases and resulted in removal of 5 duplicates.

Inclusion criteria

To be eligible for inclusion, a study had to (1) investigate inquiry-based learning in math, physics, chemistry, biology, or general science with learners between the ages of 5 and 22; (2) compare a group of learners that were supported during an inquiry with a comparison group that neither received this support nor any alternative form of guidance; (3) either randomly assign learners to one of these two groups, confirm the comparability of both groups in preliminary analyses, or control for possible pre-existing differences in the main analyses; and (4) assess the effects of the support under study on participants’ learning activities, performance success, or learning outcomes, and report these effects quantitatively by means of descriptive or inferential statistics.

The first three criteria were used in an initial screening of the studies’ abstracts. If no abstract was available, the full publication was collected and examined. This first round of selection resulted in the provisional inclusion of 216 studies. In order to reach a final decision, these studies were retrieved from an online library or requested from the author. The 213 studies that were eventually obtained were considered by both authors for inclusion. After differences in judgments were discussed, the authors agreed that 74 studies met all four inclusion criteria, however 7 studies had to be excluded based on a lack of descriptive statistics. As 5 of the 67 remaining studies reported on two experiments with separate samples, the final number of studies included in this meta-analysis was increased by 5, bringing the end total to 72.

Outcome measures and moderator variables

From these final studies, descriptive statistics were gathered for three outcome measures: learning activities, performance success, and learning outcomes. Learning activities referred to what participants did during the inquiry, performance success indicated what learners managed to achieve during the inquiry, and learning outcomes
concerned what participants had learned from the inquiry. To explore possible differential effects on the outcome measures, seven moderators were extracted from the studies (see Table 2).

Table 2
Moderator Variables Used in this Meta-Analysis.

<table>
<thead>
<tr>
<th>Moderator</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome focus</td>
<td>Inquiry skills, regulative skills, domain knowledge</td>
</tr>
<tr>
<td>Publication type</td>
<td>Journal article (IF ≥ 1.5), journal article (IF &lt; 1.5), conference paper, dissertation</td>
</tr>
<tr>
<td>Domain</td>
<td>Maths, physics, biology, chemistry, science</td>
</tr>
<tr>
<td>Experimental setting</td>
<td>Research lab, classroom</td>
</tr>
<tr>
<td>Duration</td>
<td>Single session, multiple sessions</td>
</tr>
<tr>
<td>Type of support</td>
<td>Process constraints, status overviews, prompts, heuristics, scaffolds, explanations</td>
</tr>
<tr>
<td>Age group</td>
<td>Children (5-12 years), teenagers (12-15 years), adolescents (15-22 years)</td>
</tr>
</tbody>
</table>

Note. IF = impact factor.

Internal consistency of the outcome measures extraction and coding was determined by having the first and second author score all studies independently. Inter-rater agreement on learning activities, performance success, and learning outcomes was high with an overall Cohen’s κ of .91. All disagreements were resolved by discussion. Moderator coding for straightforward study features was primarily done by the first author, who consulted the second author when in doubt. Coding for the study features that required a subjective interpretation of the rater were preceded by inter-rater reliability assessments. Toward this end, the first and second author independently scored a set of 33 randomly selected studies. Agreement scores (Cohen’s κ) were .83 (type of support), .91 (age group), .94 (experimental setting) and .91 (outcome focus). After disagreements were resolved by discussion, the first author coded the remaining studies.

Computation of effect sizes
Standardized mean differences were computed for each outcome measure by dividing the difference between the mean scores of the treatment group and the control group by the pooled standard deviation. When means or standard deviations were not reported, effect sizes were obtained from inferential statistics (t, χ², and F) or raw data. Where possible, effect sizes of learning outcomes were based on gain scores so as to compensate for potential a priori differences between conditions. In studies that provided both pre-test and post-test data, the mean gains and standard deviations were calculated according to methods proposed by Lipsey and Wilson (2001). If neither gains nor pre-post scores were available, the means and standard deviations of the post-test scores were used to calculate the effect size. Effect size estimates of all outcome measures were corrected for small sample bias using the procedure by Hedges and Olkin (1985). This unbiased effect size index will be indicated by the parameter d throughout this meta-analysis.

The methods proposed by Borenstein, Hedges, Higgins, and Rothstein (2009) were used to deal with dependencies within a single study. For studies with multiple independent subgroups, first the summary data for the full study was recreated, and then this merged data was used to compute the effect size. In studies with multiple
treatment groups, the approach taken depended on the nature of the support. If the support was of the same type, a composite effect size was calculated by averaging the effect sizes obtained in the various treatment groups. This effect size was computed based on the variance of each effect size as well as their intercorrelation. If different types of support were assessed within the same study, the type of support that best matched the study’s goals and research questions was selected or, if this proved impossible, one type of support was selected at random.

A similar approach was used to address dependencies in studies reporting multiple scores or sub scores for a single outcome measure. As with multiple treatment groups, the preferred option was to compute a combined effect size and calculate its variance by taking into account the correlation among the separate scores. When this correlation was not reported, the most relevant score was selected or, as the second-best alternative, selected at random.

Data analysis
To test this meta-analysis’ first hypothesis, the summary effect of supported versus unsupported inquiry learning was compared for each outcome measure. Inverse variance weights were used to assign more weight to effect sizes from studies with larger samples. The significance and homogeneity of the summary effect was determined by Z and Q-tests. When homogeneity of the summary effect could not be confirmed, the first five moderators from Table 2 were analysed through Q-tests based on analysis of variance. Analog to a one-way ANOVA, this test indicated whether the between-group variance ($Q_b$) was statistically significant. If so and where appropriate, planned contrasts were conducted to identify significant differences across moderator categories.

$Q_b$ was also used to test the second hypothesis, which predicted that the overall mean effect size was related to the type of support. When homogeneity of effect sizes across the six types of support was rejected, planned contrasts were calculated to indicate which types of support differed significantly from each other. The $Q$-tests’ within-group variance ($Q_w$) was used to test the third hypothesis that more explicit types of support are more effective for younger learners. The $Q_w$ homogeneity statistic indicated whether it is reasonable to assume that studies investigating the same type of support share a common effect size. With support types for which this assumption was disproved, planned contrasts were performed to examine whether the heterogeneity was attributable to the learners’ age group.

Table 3  
<table>
<thead>
<tr>
<th>Process constraints</th>
<th>Status overviews</th>
<th>Prompts</th>
<th>Heuristics</th>
<th>Scaffolds</th>
<th>Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Teenagers</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Adolescents</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>3</td>
<td>11</td>
<td>4</td>
<td>22</td>
</tr>
</tbody>
</table>

Results
Table 3 characterizes the studies included in this meta-analysis in terms of their type of support and age group. Regarding age, the number of studies addressing children (22), teenagers (22), and adolescents (27) was well
balanced; the distribution of type of support was somewhat skewed with two-thirds of the studies focusing on scaffolds and explanations. As this disproportionate emphasis on the more specific types of support was independent of age group, \( \chi^2(10) = 7.69, p = .659 \), data analysis could proceed as planned.

Table 4
Summary of Effect Sizes.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Studies</th>
<th>N</th>
<th>d</th>
<th>95% CI</th>
<th>Z</th>
<th>( p_z )</th>
<th>( Q_b )</th>
<th>( df_q )</th>
<th>( p_q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning activities</td>
<td>20</td>
<td>2,374</td>
<td>.71</td>
<td>[.63, .80]</td>
<td>16.15</td>
<td>.00</td>
<td>82.32</td>
<td>19</td>
<td>.00</td>
</tr>
<tr>
<td>Performance success</td>
<td>17</td>
<td>1,019</td>
<td>.66</td>
<td>[.53, .79]</td>
<td>9.88</td>
<td>.00</td>
<td>31.72</td>
<td>16</td>
<td>.01</td>
</tr>
<tr>
<td>Learning outcomes</td>
<td>60</td>
<td>5,629</td>
<td>.46</td>
<td>[.41, .52]</td>
<td>16.38</td>
<td>.00</td>
<td>253.09</td>
<td>59</td>
<td>.00</td>
</tr>
</tbody>
</table>

Table 4 presents the summary effects for the three outcomes measures. Results for the first research question showed that support has a significant, medium effect on learning activities, performance success, and learning outcomes. As the Q-tests indicated that these effects were heterogeneous across studies, moderator analysis was performed to examine the impact of the basic study features listed in Table 2. The effect sizes of learning activities and performance success proved independent of publication type, domain, experimental setting, duration, and outcome focus (\( Q_b < 3.91, p > .07 \)). With learning outcomes, however, a significant effect was found for publication type, \( Q_b(3) = 8.42, p = .036 \). Planned comparisons revealed that journal articles (\( d = .56 \)) contained higher effect sizes than conference papers and dissertations (\( d = .24 \)), \( Z = 2.04, p = .021 \), and that studies published in first-tier journals (\( d = .65 \)) report significantly higher effect sizes that studies from second-tier journals, (\( d = .38 \)), \( Z = 1.80, p = .036 \). Outcome focus also moderated the findings, \( Q_b(1) = 9.43, p = .002 \), with significantly higher effect sizes for studies assessing inquiry skills (\( d = .78 \)) than studies assessing domain knowledge (\( d = .37 \)). The remaining moderators were not statistically significant, \( Q_b < 2.84, p > .136 \).

To address the second research question, the influence of the moderator ‘type of support’ was analysed univariately. Between-group homogeneity tests showed that the variance of effect sizes in performance success was moderated by the type of support, \( Q_b(5) = 14.34, p = .014 \), with higher effect sizes being associated with more specific support, \( r = .53, p = .030 \); no significant moderation effect was found for learning activities, \( Q_b(5) = 4.01, p = .547 \), and learning outcomes, \( Q_b(5) = 4.05, p = .542 \). Planned contrasts on the performance success data showed that explanations (\( d = 1.84 \)) were more effective than all less specific types of support combined, \( Z = 1.84, p = .033 \). Along the same lines, a close to significant difference was found for scaffolds (\( d = .85, Z = 1.45, p = .073 \)) whereas heuristics (\( d = 1.17 \)) were significantly more effective that their less specific alternatives, \( Z = 1.72, p = .043 \). Prompts (\( d = .50 \)) were as effective as status overviews and process constraints combined, \( Z = .25, p = .401 \), and status overviews (\( d = .22 \)) were less effective than process constraints (\( d = .71, Z = 2.01, p = .023 \)).

Analyses for the third research question examined whether the within-group variance of each type of support was significant and attributable to the learners’ age. Significant heterogeneity was found in the overall effect of support on learning activities, \( Q_w(14) = 24.50, p = .040 \), but not in performance success, \( Q_w(11) = 15.42, p = .164 \), and learning outcomes, \( Q_w(54) = 62.73, p = .194 \). Follow-up analyses for learning activities revealed a close-to-significant variation in process constraints, \( Q_w(3) = 7.32, p = .062 \), and scaffolds, \( Q_w(5) = 9.77, p = .082 \).
Planned contrasts showed that children ($d = .78$) benefit less from process constraints than adolescents ($d = .94$), but not to a statistically significant degree, $Z = .53$, $p = .300$. However, scaffolds turned out to be more effective for teenagers ($d = 3.62$) than for adolescents ($d = .70$), $Z = 2.52$, $p = .006$.

**Discussion**

The data reported in this meta-analysis confirms our first hypothesis that inquiry learning support has a significant positive effect on learning activities, performance success, and learning outcomes. The magnitude of these effects was medium in that differences between the supported and unsupported condition was approximately half a standard deviation. These findings are consistent with previous meta-analyses that compared guided inquiry learning with other instructional approaches (e.g., Alfieri et al., 2011; Furtak et al., 2012). Surprisingly, however, there have been no direct meta-analytical comparisons of supported vs. unsupported inquiry learning, so the present study adds to the research literature by showing that similar benefits of support appear in a more strict comparison within the domains of maths and science. Also of interest is that the positive effect of support was consistent across all three outcome measures, although higher effect sizes were found for outcome measures more directly related to the learning process where the support was available. Meaning that the effects of inquiry learning support extend beyond measures of learning outcomes typically included in meta-analytical studies.

The overall effect of inquiry learning support on learning outcomes was moderated by publication type and outcome focus. The former confirms the existence of publication bias in educational science: studies with large positive effects are more likely to be published in general, and in high-quality journals in particular, than studies with non-significant or ‘negative’ results. The moderating effect of outcome focus indicates that inquiry learning support has a larger impact on skill development than on the acquisition of domain knowledge. One plausible explanation is that the support included in this meta-analysis was exclusively geared toward inquiry skills; inducing knowledge by performing these skills is possible but at the same time susceptible to errors not necessarily addressed by the support. Surprisingly, neither the experimental setting nor the study’s duration moderated the findings. This contradicts the common concern that inquiry learning interventions are studied for a too short period of time and under (too) controlled circumstances (e.g., De Jong & Lazonder, 2014; Kuhn, et al., 1995). This meta-analysis proved otherwise, and implies that the true effects of support can be revealed in short-term studies conducted in either researcher-controlled settings or authentic learning environments. Finally, none of these basic study features moderated the effects on learning activities and performance success. As the differences in effect sizes resembled those of learning outcomes, the absence of any significant moderator effect might be due to the comparatively small number of studies assessing these outcome measures. Alternative explanations are advanced in the paragraphs below.

The second research question concerned the relative effectiveness of different types of support. More specific support such as scaffolds and explanations was expected to yield larger effect sizes than less specific support like process constraints or prompts. This hypothesis was partially supported by the results. The overall mean effect size for learning activities and learning outcomes was independent of the type of support, but a moderator effect was found in performance success. The rank correlation confirmed that larger effect sizes were associated with more specific types of support, and planned contrasts revealed that most cross-support type differences were significant. It thus seems that learners perform better during an inquiry (i.e., create better products to exhibit their domain
knowledge) when supported by more specific forms of guidance. This conclusion raises the question why the type of support did not affect learning outcomes, which in 42 of the 60 studies concerned domain knowledge. Part of the answer lies in the lower effect sizes for domain knowledge compared to inquiry skills. In keeping with the aforementioned explanation, offering more specific support has an immediate effect on the domain knowledge articulated during the inquiry, but these initial differences fade away quickly after the instructional context is withdrawn. This reflects the incommensurability between learning and performance: instructional interventions designed to increase performance during the learning task are often less effective in increasing learning in the long term (Kapur & Rummel, 2012). The support included in this meta-analysis was at the skill level, and might therefore be less appropriate to promote learning.

In light of this explanation one would expect the type of support to moderate learning activities. This was not the case, but the considerable within-group variance points to a differential effect that could be due to the learners’ age. This effect was most apparent for process constraints and scaffolds, and consistent with the assumption that more specific types of support are more beneficial for younger learners. Still, the number of studies in this analysis was rather low which does not allow for any definitive conclusions. Other factors not included in the moderator analysis could have caused the within-group variation as well, for example the wide variety of measures used to indicate learning activities. These ranged from the number of unconfounded experiments through the number of re-studied assignments to the time spent reading potentially relevant websites. In absence of any strong evidence, it seems that at least for now the answer to the third research question is that the effectiveness of inquiry learning support is independent of the learners’ age.

In conclusion, this meta-analysis demonstrated the importance of supporting inquiry learning across age groups. Learners who are supported during an inquiry act more skilfully, perform better, and learn more than their unsupported counterparts. Even though the specificity of the support makes no difference in how much is learned from the inquiry, behaviour and performance during the inquiry increases more with more specific types of support. This effectiveness seems independent of the learners’ age, but more research is probably needed to arrive at a definitive conclusion. Maths and science teachers are therefore recommended to support their students during inquiry-based lessons. Teachers aiming to maximize students’ performance during an inquiry should offer the most specific support possible; teachers interested in promoting more sustainable learning outcomes can opt for less specific types of support as well.

**Acknowledgments**

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The role of teacher-led class interventions in scaffolding web-based collaborative inquiry
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Abstract
In the context of a design-based research project investigating web-based collaborative inquiry in secondary education, this paper presents the fifth intervention study exploring the effects of teacher-led class interventions. Building on previous iterations it is hypothesized that next to technology-enhanced scaffolding, scaffolding through peers and teacher-team interactions, teacher-led class interventions are necessary to satisfy students’ basic needs and (indirectly) will improve motivation for science learning and students’ performance and achievement during web-based collaborative inquiry. This has been investigated through a quasi-experimental study comparing the experimental condition (N = 87 students from 5 classes) - in which teacher-led class interventions were provided - with a control condition (N = 81 from 5 classes). Based on preliminary results it can be concluded that the provision of structure and feedback by the teacher through class interventions statistically affects students’ competence satisfaction, which is one of the basic needs. All students - regardless of condition - made significant improvement in intrinsic motivation for science learning, yet competence frustration has been found to negatively influence the increase in intrinsic motivation. Moreover, gender differences in competence satisfaction have been found which confirm the need to differentiate during web-based collaborative inquiry. Further analyses - which will be presented at the SIG meeting - will investigate if a higher competence satisfaction / lower competence frustration also leads to higher performance results (i.e. the process scores and the individual knowledge and inquiry performances in pre- and posttest).

Theoretical background
In line with the advent of computer-supported collaborative learning in authentic classroom practices, we also face the challenge to rethink the notion of scaffolding from a multilevel approach (Raes & Schellens, 2013). External scripting as a means to scaffold the individual and collaborative activities can be put into practice by three external sources. First, technology-enhanced scaffolds can support individuals or small groups through their inquiry processes (Morris et al., 2010). Second, peer learners can be considered as a source of scaffolding regulation during inquiry (Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003) and third, also the teacher remain to have a crucial role in scaffolding the individual and group processes which in CSCL is referred to as orchestration of the complex classroom (Dillenbourg, Järvelä, & Fischer, 2009).

Dillenbourg (2012) defines classroom orchestration as “Real time management of multi-plane multi-layer activities that maximize satisfaction and minimize entropy”. This perspective brings along (re)new(ed) attention in research and design for the role of the teacher. Regarding for example the learning environment WISE (Slotta & Linn, 2009), the fourth version of WISE has new teacher tools including the Progress Monitor to view student work online in real-time and the Pause Screen feature to pause work on student computers simultaneously.

Research objectives and hypothesis
The learning environment WISE has been used from 2009 to investigate web-based collaborative inquiry in educational practice from a design-based research approach. The fifth and latest intervention study was set up...
building on what we learned from previous iterations and wants to shed light on the effects of classroom level interventions by the teacher. Previous study investigated students’ evaluations of the learning approach and indicated that the basic needs for motivation (i.e. autonomy support, competence support and relatedness support, see Vansteenkiste, Sierens, Soenens, Luyckx, & Lens (2009) were not fully satisfied (Raes & Schellens, under review). A lot of students stress that they would only like to be taught with WISE in future science education in combination with traditional teacher-centered education. Moreover students often mentioned the need of the teacher as handhold during (information) problem solving on the web since they worry about the reliability of web-based information.

In this regard, the hypothesis is that next to technology-enhanced scaffolding, scaffolding through peers and teacher-team interactions, teacher-led class interventions are necessary to satisfy students’ basic needs and will (indirectly) improve students’ motivation for science learning, students’ performance during web-based collaborative inquiry and their knowledge achievement.

Method
In line with the design-based research approach, a similar intervention as previous years (see Raes, Schellens, & De Wever, In Press) was set up with the same WISE-project about Global Warming and the same student population (grade 9 & 10). In this study the experimental condition differed from the control condition in the way the teacher interacted with the classroom as shown in Figure 1. In the control condition the teacher only gave a practical oriented introduction in every session and was available for help and interacted with the different teams to support them. In the experimental condition, next to ‘making rounds’ the teacher led a class intervention in between every session following a predefined protocol which particularly aimed at providing structure and feedback to improve competence satisfaction.

Figure 1
The pretest-posttest quasi-experimental design

A mixed-method approach was used to obtain both quantitative and qualitative data. The quantitative data consisted of the individual pre- and posttests measuring knowledge, inquiry skills and motivation for science (Vansteenkiste et al., 2009); group performance scores during the WISE-project; and the perceived basic psychological need
satisfaction (BPNS, Deci & Ryan, 2000) and perceived teacher support (TASC, Belmont, Skinner, Wellborn, & Connell, 1988) measured through posttest). Qualitative data consisted of observed interaction processes of 32 teams and a logbook per class.

**Results & discussion**
In this paper we only present the results of students’ perceived teacher support, their basic need satisfaction and the effects on motivation for science. First a manipulation check was conducted based on the TASC questionnaire (measuring how students did experience the teacher’s provision of structure) and the classroom logbooks. Based on these results two classes were excluded to improve reliability: one due to a delayed posttest, one due to a bad cooperation with one of the teachers who had totally neglected the protocol. After excluding these classes the results confirm that the experimental condition (M = 5.17, SD = 0.74) experienced a significantly higher provision of structure compared with the control condition (M = 4.78, SD = 1.11) (t(119) = -2.14, p = .03).

Regarding the basic need satisfaction it has been found that students in the experimental condition are statistically more competence satisfied (t(119) = -2.54, p < .05) and less competence frustrated (t(119) = 3.03, p < .01). Students in the experimental conditions are also more relatedness satisfied, but this is only marginally significant (t(119) = -1.8, p = .07). No difference between the conditions was found regarding autonomy satisfaction (t(119) = -1.58, p = .12). When investigating individual differences, it has been found that girls indicated more competence frustration whereas boys indicated more competence satisfaction.

Regarding intrinsic motivation, an overall increase was found from pre- to posttest (t(116) = -4.10, p <.01). No effect of condition was found (F(1, 116) = 0.29, p = .59), but competence frustration has been found to negatively influence the increase in intrinsic motivation (B = -.23, t(116) = -2.51, p < .05).

We can conclude that the provision of structure by the teacher is important and positively affects students’ competence satisfaction. No difference was found regarding autonomy satisfaction, which was in both conditions positively (significantly different than neutral) evaluated and is consistent with the finding of an overall improvement of intrinsic motivation for science learning in both conditions. The found gender differences in basic need satisfaction confirm the need to differentiate (Raes, Schellens, De Wever & Vanderhoven, 2012).

Further analyses – which will be presented at the SIG conference - will investigate the connection between competence satisfaction and performance.

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The impact of mobile devices towards learning and instruction in secondary education

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Abstract
This poster reports the introduction of a computer-supported learning tool, namely the tablet device, in a secondary school in Belgium. This school, and so far the only school in Belgium, has implemented the devices into the whole classroom organisation. Moreover, tablet devices are implemented in all grades and all courses. The introduction of tablet devices in this school has developed from the vision of the schoolboard that education has the purpose to prepare pupils for participating the technological society. After using these devices for six months, a qualitative focus group study has been organized with teachers (n=18) and pupils (n=36). Results show that the introduction has an impact towards learning and instruction. Moreover, teachers can be distinguished into two categories, namely the innovative and the instrumental teachers. This division has consequences on the way of giving courses. While instrumental teachers are stuck on giving classes on a traditional way; innovative teachers try to implement inquiry-based and rich multimedia-integrated courses. These results indicate that the role of innovative teachers should be promoted and attention should be given to digital didactics. Finally, the introduction of these devices includes the need of both technical (such as adapted didactical material) and professional support among teachers. These results should be further discussed at the conference.

Introduction
In order of the transformation to the Information Society (Kozma, 2005), several authors (e.g., Figueiredo & Afonso, 2005; Pelgrum, 2001) pointed to the needed shift from a traditional classroom where teachers have to fill in empty minds of the learners which are seen as passive consumers of educational transfer to learners who are considered as active participants in learning where participation, collaboration and where sharing knowledge in interactive, media-rich and exciting learning environments is beneficial to foster active learning (Barak, Lipson, & Lerman, 2006). In this respect, the growing interest in mobile technology is understandable. It is flexible, students have control over the learning process and can work, individually or collaboratively on complex inquiry-based tasks. Despite the alleged potential these devices might provide to the learning environment, the role of the teacher is often underexposed. In this regard, teachers beliefs towards the innovation plays a significant impact on the rate of adoption of this kind of technology (Vanderlinde & van Braak, 2011).

Results of Becker & Ravitz (1999) stated that teachers can be categorised in two groups, namely teachers with a more constructivist approach on the one hand, and teachers with a more behaviorist approach on the other hand. Consequently, an understanding of these beliefs is a first step in the development of a deeper understanding of innovation in complex classroom practices (Hermans, Tondeur, van Braak, & Valcke, 2008). Because teachers play a pivotal role in implementing educational innovation (Vanderlinde & van Braak, 2011), the implementation of technology demands a lot from them. Moreover, the teachers are challenged to integrate educational technology into
the classroom (Williams, Coles, Wilson, Richardson, & Tuson, 2000), which requires the need of adopting both technological and pedagogical skills to integrate the given technology into their daily classroom practices (Clark & Luckin, 2013). In the little existing research, teachers reported that using tablet devices transformed their teaching practices, and made them rethink the professional role (Burden, Hopkins, Male, Martin, & Trala, 2012; Clark, & Luckin, 2013). This transformation included not only instrumental advantages, but it also enabled the teachers to provide a wider range of learning activities which were previously not possible and which promote independent learning (Burden et al., 2012; Heinrich, 2012). However, teachers do not feel apt to use this educational technology and ask for additional technological and pedagogical feedback (Heinrich, 2012). In addition, teachers’ attitudes and viewpoints towards technology play a central role in the perceptions of their students towards technology (Hu, Clark, & Ma, 2003).

**Research question**

Despite ample interest, not much is known about the perceptions of the important stakeholders on the impact of tablet devices in secondary education. This paper fills in this gap by investigating the first perceptions of pupils and teachers in a pioneer school in Belgium. Understanding these perceptions could help to integrate technology in the classroom and thereby improving and enhancing the learning process. In other words, the main question in this study concern the perceptions of both stakeholders towards the impact of mobile devices on learning and instruction.

**Method**

A qualitative focus group study with pupils (n=36) and teachers (n=18) has been conducted in one of the first secondary schools in Belgium that has implemented tablet devices, namely iPads, into the whole school -and classroom organization since September 2012. Moreover, tablet devices are implemented in all grades and courses. The introduction of tablet devices in this school has developed from the vision of the schoolboard that education has the purpose to prepare pupils for participating the technological society. Semi-structured questions were formulated to encourage conversation and the focus groups, setted up according to the guidelines of Morgan and Krueger (1998), were filmed and transcribed. Data will be analyzed using a two-step procedure (Miles & Huberman, 1994). In the first step of the data analysis, a vertical analysis was applied leading towards results for each individual focus group. A coding scheme was used with a special focus on learning and instruction. In the second data analytic step – the horizontal analysis –, a systematical comparison of the results of the vertical analysis was conducted by looking for similarities and differences. The use of focus group interviews is a common method for gathering information in qualitative educational research (Puchta & Potter, 2004), especially for those research designs where no solid information is yet available in research literature. Setting up a focus group study was relevant in this context to gather explorative information about the perceptions of the most important stakeholders using tablet devices in this pioneer school.

**Results & discussion**

Two kinds of teaching styles occur during the implementation process of tablet devices: the ‘instrumental teachers’ versus the ‘innovative teachers’. The instrumental teachers are defined as those who have not changed their role and believe the device has a mainly instrumental value. Furthermore, these teachers continue to perform their role in the same way with the main difference that the tablet device replaces the textbook. “The teachers stayed pretty much...
the same” (student). Surprisingly, implementing innovative technology strengthened those teachers with an instrumental role to become more conservative. By contrast, the ‘innovative teachers’, are teachers who take on the role of coach, changed their teaching style and transformed their lessons according to the possibilities that tablet computers offer, and use more didactical applications beside the text-processing ones. Furthermore, these teachers organize their courses in order that pupils learn on a inquiry-based way, by searching on the Internet for additional information or by manipulating objects in order to improve learning. “Using tablet computers increased the educational opportunities (teacher). For example: pupils learn about mathematics by calculating hyperboles on their own photographs of horse jumping or playing football.

Furthermore, first results indicate that participants express the teachers’ need of additional support. When focusing on the material side, participants pointed to the availability of an adequate infrastructure and a strong IT-team that encourages the integration of tablet devices. Pitfalls are situated on the lacking adapted digital material. Editors cannot follow or provide adapted digital material causing teachers to feel pressured to take over the role of authors; which causes a high workforce and uncertainty to integrate tablet devices into courses. Mixed feelings concerning the need of professional development can be formulated. While some teachers and older pupils express the need of more professional training courses, other teachers state that they have no energy left for additional training or indicate the lack of adequate training.

As a conclusion, these preliminary results show that the introduction of tablet devices provokes different perceptions about learning and instruction. Moreover, conducting a policy, in which attention is given to an adequate preparation of teachers, attention to digital didactics, adapted didactical material and provision of technical and pedagogical support to stimulate stakeholders’ recognition of tablet devices’ potential in education remains necessary. These results should be further analyzed and discussed at the conference.

References


Qualitative development of understanding in an elementary school inquiry-based science context
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Abstract
This paper reports on a study in which 10-12 years old students learned about electricity circuits through inquiry activities with an electricity simulation. Another paper on this same study reported that students improve considerably from the pre- to the post-test as a result of engaging in inquiries with the simulation, but also differences with respect to the knowledge development depending on the grade level of the students.

These results analyze singular items with respect to the correct model, while literature suggests that students have many (partially) incorrect models of electricity, and in fact these models guided the design of the inquiry activities, addressing first open and closed circuits, then moving to single and multiple series circuits (first qualitative then quantitative), and from there to series and parallel circuits (qualitative and quantitative). The aim of the current paper is to analyze students’ answers on a more qualitative level connecting the items with models of (mis)understanding circuits in order to reveal more detail with regard to the students’ knowledge development during their inquiry activities with the simulation. The study followed a pre-, intervention, post-test design with 127 participants (4th=34; 5th=25, and 6th=68 grade). The results show considerable improvement of the number of students that show full: qualitative understanding of open and closed circuits with one bulb or two bulbs in series; qualitative understanding of serial and parallel circuits; and quantitative understanding of these circuits, but also that after the intervention many of the students (especially 4th graders) still have an incomplete understanding of the circuits. These results amended with further analyses suggested in the paper will provide implications for both further research and the development of inquiry activities in this domain.

Introduction
This paper reports on a study in which 10-12 years old students learned about electricity circuits through inquiry activities with an electricity simulation. The aim of the inquiry activities is that students learn that for a bulb/resistor to be part of a (closed) circuit, it must be connected to the two terminals of the battery (open-closed circuit); and that the potential difference over components or brightness of bulbs in a circuit depends not only on the number of components, but also on the configuration of the circuit (series-parallel).

In another paper on this same study, it is reported that students improve considerably from the pre- to the post-test as a result of engaging in inquiries with the electricity simulation, but also that there are differences with respect to the knowledge development depending on the grade level of the students. Especially in grade 4 the students were not reaching very high levels of knowledge on the post-test. This raised our interest into finding out more about what it is exactly that the students learn when they are engaging in the inquiry activities, and if there are obstacles with regard to the knowledge that are difficult to overcome for students.
The results that showed considerable knowledge gain looked at the scores of students on the pre and post-tests from a classical test theory point of view, assessing the pre- and post-test reliabilities (α=.85 and .92 respectively) and counting the number of correct of answers to come up with a total score for pre- and post-test. While these reliabilities suggest a high internal consistency, this consistency refers to the full correct model, while there is ample literature that suggests that students have many (partially) incorrect models of electricity (Shipstone, 1984; Reiner et al. 2000). In fact these models from the literature guided the design of the inquiry activities, addressing first open and closed circuits, then moving to single and multiple series circuits (first qualitative then quantitative), and from there to series and parallel circuits (qualitative and quantitative).

Therefore, the aim of the current paper is to analyze students’ answers to the pre and post-tests on a more qualitative level connecting the items used in the tests with models of (mis)understanding circuits in order to reveal more detail with regard to the students’ knowledge development during their inquiry activities with the simulation.

**Methods**

*Participants and design*

The participants were 127 4th (n = 34) 5th (n = 25), and 6th (n = 68) grade students from Finland. The objective was to use a computer-simulation to discover the basics of series and parallel electric circuits (see Figure 1). The students had no previous formal education in electricity.

*Procedure and materials*

The empirical phase of the study had a pre-test intervention post-test design. On the pre-test students completed a subject knowledge assessment questionnaire to measure the initial level of students’ conceptual understanding of electric circuits. Based on matched pre-test score pairs, students were placed randomly into the conditions. During the intervention, students engaged in inquiry activities around constructing and studying various circuits in the concrete or fading condition. The students had 90 minutes to complete as many of the total of 9 circuit inquiry worksheets as possible. In order to compare the relative effectiveness of the learning conditions and assess the changes in students’ conceptual understanding of electrical circuits, the students completed a subject knowledge post-test questionnaire one day after the intervention.

*Results and Discussion*

In the preliminary analyses reported in this paper the focus is on the first group of 5 items that primarily assess the students understanding of closed and open circuits and single and multiple (2) bulbs is series, and 2 groups of 7 items (one with bulbs, the other with resistors) that primarily meant to assess quantitative understanding of bulb/resistor in single bulb, and multiple bulbs/resistors serial and parallel circuits.

The results for the first group of questions show that 38 students (4th=6; 5th=8; 6th=24) had a qualitative understanding of open and closed circuits with one bulb or two bulbs in series while 70 students (4th=14; 5th=12; 6th=44) showed such understanding on the post-test ($\chi^2 < 0.01$).

The 2 groups of 7 items on serial and parallel circuits were recoded in a way that their results reflect the students qualitative understanding of the circuits, and these results show that only 3 students (4th=0; 5th=0; 6th=3) have a full qualitative understanding of open and closed serial and parallel circuits on the pre-test, whilst 22 students (4th=1; 5th=5; 6th=16) have on the post-test ($\chi^2 < 0.01$). From these 22 students, 21 (all but the 4th grade student) also showed quantitative understanding of these circuits ($\chi^2 < 0.01$). This suggests that the crucial factor is qualitative
understanding, as our results suggest that quantitative understanding almost automatically follows from qualitative understanding.

While these results certainly indicates improvement, they nevertheless also indicate that the many of the students still have incomplete understanding of the circuits as they were presented to them in the post-test. One explanation could be that some of the items depicted realistic circuits, while the simulation only used schematic representation. Comparing the students on their understanding of realistic vs schematic circuits could reveal this, and if this is the case it would suggest against primarily using schematic simulations, as the goal of the inquiry activities is generic understanding of electric circuits, not schematic circuits alone.

In the coming period before the conference we intend to conduct this and further analyses to uncover to what extent the students that do not make the transition from incomplete understanding of open and closed serial circuits, and to what extend those who do make this transition, but not to understanding serial and parallel circuits still improve their understanding of electrical circuits. These results should reveal which transitions prove particularly difficult, and provide suggestions for the focus of instruction for future research and development productive inquiry environments in this domain.

References
Analysing tablet-enhanced inquiries in elementary science education
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Abstract
This paper presents primary findings of a study on inquiry-based learning with tablet-cloud systems in elementary science education. The study is investigating the situated ways in which 8 to 12 year old students (n=240) make sense of science phenomena through ICT-enhanced inquiry processes. In science education, inquiry is emphasised both as a means and an outcome. Student-centred inquiry is a promising way of learning that encourages students to explore the world and engage in critical thinking. Scientific inquiry skills are a core outcome of probably any science education. After proliferating in everyday contexts, high performing mobile devices are entering learning environments right now. But up to date, little is known about how to integrate these devices into inquiry-based science learning. Our study analyses how mobile devices re-shape the learning landscape of the inquiry-based science classroom, i.e., to what extent they facilitate the learner-led exploration and understanding of scientific phenomena and the formation of scientific thinking. Evidence is gathered through data collected by researchers (video recordings from science lessons) and students (uploading multimodal classroom productions on internal school clouds). The preliminary analysis shows that integrating tablets into the science class is increasing the student-initiated gathering of own data and supporting interactive forms of inquiring. Moreover, technology-enhanced inquiry learning is becoming more learner-centred and open when the use of tablets is guided by a series of well-designed hands-on activities together with multiple interaction opportunities (collective or collaborative). Students quickly acknowledge the potential of these devices for gathering information, (re)-evaluating own explanations, fully documenting their science investigations, communicating targeted inquiry results or reflecting on their learning.

Learning with tablets

Mobile and interactive devices advance more and more as our favourite tools to engage in web activities (Nielsen & NM Incite, 2012), which stir interactions and spur interest. They offer powerful means (Sharples & Roschelle, 2010) to create and share content or to get acquainted with a body of knowledge. In everyday life, learning often occurs as a side-effect of activities people are engaged in and is theorised as “incidental” (Marsick & Watkins, 1990), “informal” (Cross, 2007), or “tangential” (Portnow, 2008). These notions share the idea that learners - rather than getting institutionally directed and controlled (Cofer, 2000; Ala-Mutka, 2010) - educate themselves (e.g. set own goals and objectives) if they get introduced to topics they appreciate in a context they find engaging (Fischer, 2011).

Nowadays, tablets are fascinating people of all age. After proliferating in everyday contexts, these high performing mobile devices with extended sensing features start entering classroom contexts (Culén & Gasparini, 2012; Henderson & Yeow, 2012; Jahnke et al., 2013). A myriad of educational applications is being offered for all kind of classroom use. First experiences in classrooms describe these devices as promising means to improve
learning in respect of the 21st century challenges (Leonard, 2013). But so far, only little evidence is provided about ways to successfully integrate these devices into inquiry-based learning approaches (Crismond, 2011; Hong et al., 2013) thanks to the device’s potential to a) gather own data, b) facilitate multimodal and multimedia productions c) back interactive forms of collaborative learning.

**Modes of inquiry**

The introduction of new technologies in education has often been seen as catalyst for change (Melhuish & Falloon, 2010) whereas history tells us that implementation efforts mostly struggled to achieve the high expectancies (Cuban, 2003; Cox et al., 2003). Many argued already about the potential of ICT to support and facilitate inquiry-based learning and student-centred teaching practices (Blumenfeld et al., 1991; Hakkarainen, 2003; Marx et al., 2004). Inquiry is conceived as an active way of learning, which stimulates students to explore the world, construct knowledge through own investigations, engage in critical thinking and participate in collaborative learning activities. Especially, the versatile use of tablets might support students’ inquiry processes (e.g. active creation of knowledge through the pursuit of open-ended questions, data gathering, evidence-based explanations, collaborative discussions) by a) enriching and structuring problem contexts, b) facilitating the utilization of resources, c) supporting cognitive and metacognitive processes (Wang, 2009). The introduction of mobile technologies in classrooms generates technological, organisational and pedagogical challenges and should be fully merged and fused with social practices of teachers and students (Hakkarainen, 2009).

**Research question**

The present study investigates the impact of tablet-cloud systems on inquiry-based learning practices in elementary science education, i.e., to what extent do they facilitate student-led explorations and explanations of scientific phenomena, stimulate creative classroom productions, support topic understanding and the formation of scientific thinking. Moreover, we explore how learning emerges as a somewhat nonlinear and dynamic process resulting from multimodal interactions with peers and competent others (Vygotsky, 1978) in socio-digital activity systems (Engeström et al., 1999)

In order to better understand the nature and process of ICT-enhanced inquiry-based learning, we explore how five essentials - question, evidence & analysis, explain, connect, communicate - are enacted in science lessons across classrooms, i.e., how they are operated by different teachers as limited, structured, guided or open forms of inquiry (NRC, 2000; Asay & Orgill, 2010) that vary from teacher to learner-directed forms.

**Data sources**

The study uses a multi-method framework which combines different data sets to gain a very complete and valid understanding of the situated learning processes. The purpose is to uncover promising inquiry practices from the moment-by-moment dynamics (micro) to unfolding classroom activities (meso) in which children make sense of science phenomena. Evidence is provided by different kinds of data, collected either by students on the internal cloud (multimodal classroom productions, self-recordings about their learning and inquiry approaches) and/or research teams (video data from science lessons, video-stimulated recall interviews with students, recordings of
teacher meetings). Data is collected in four fundamental schools, which have been equipped with sets of 20 tablets, Wi-Fi access and internal clouds. The students (n=240, 8 to 12 years old) use only applications, which allow to store data on internal school clouds. The cloud offers a) collaboration within and across student teams; b) sharing of resources among actors within and beyond the classroom, c) an easy and remote access to students’ production. The project team meets the teachers (n=10) on a regular basis to co-configure classroom practices according to participants’ needs, demands, expectancies and experiences. Students’ productions are analysed by multimodal artefact analysis (Kress, 2003; Bateman 2008) and computer mediated discourse analysis (Herring, 2007) that focus on written text and talk. Interactions/conversations at micro-level are analysed by multimodal interaction analysis (Goodwin, 2007; Sahlström, 2009) and conversation analysis (Seedhouse, 2004).

Results

Findings evidence dynamic, nonlinear and student-driven inquiry activities in science activities, even in highly teacher-structured learning environments. Students expand their inquiries through these devices from simply searching information to fully documenting science experiments, exploring scientific information, (re-)evaluating scientific phenomena and engaging into classroom discussions. Thanks to the tablets’ intuitive features and usability, the students manage to organise and converge their own data to multimodal and multimedia productions varying from simple texts to more complex multimodal productions merging text, images, sounds or videos. As most inquiry activities were designed as group work, due to the limited number of devices available, we evidenced that tablets allow to reorganise the learning space towards intense collaboration among students beyond the confined physical classroom setting. Finally, our study identified a series of well-designed hands-on activities with rich ICT-mediated interaction scenarios.

Significance and limitations

The present study is of substantial relevance for conceiving ICT-enhanced inquiry-based learning environments in school contexts. It nurtures advancements in the theoretical, methodological and pedagogical domains and is of major interest for the EARLI domain of learning and instruction in today’s socio-digital ecosystems. Regarding basic and applied research, the study produces relevant insights on the ways and the extent situated ways of thinking and acting come into being, are dialogically taken into account by other participants and might be tackled for further improvement through teachers or peers. Insights into classroom practices inform teachers and researchers about pedagogical approaches, strategies, difficulties in order to launch creative inquiry processes with table-cloud technologies in (science) education.

References


Collaborative learning in a wiki-environment:
Stimulating collaboration

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Abstract

Wikis are typically described as having a positive influence on learning and being helpful in organizing learning activities. At the same time, one of the major challenges in applying wikis seems to be how to trigger and maintain productive collaboration processes. Challenged by this, this study aims to investigate the impact of implementing a collaboration script for a wiki-task in higher education. The participants in this study were first-year university students Educational Sciences (N= 181) taking the course Instructional Sciences. Students were divided in groups of five and received a task during a three-week period in which they were asked to write a wiki together consisting of five pages and an overview page. Groups were divided randomly over two conditions: a scripted and a control condition. The main research questions were whether students’ (1) experiences (with respect to collaboration and responsibility) and (2) behavior was different in the scripted versus the control groups. The results show that although students rated the quality of their collaboration the same in both conditions, students’ questionnaires indicated that the scripted groups had higher feelings of responsibility and more joint efforts (reading, writing) than the control groups. These findings were also supported by analyzing the log-data. Log file analysis showed that students in the scripted condition indeed completed more work together and more students collaborated on the pages. For the future, this study illuminates the scripting approach in wikis as one potential way to integrate research-based knowledge in authentic higher education practices.

Research questions

Despite the educational potential of wiki-environments for education (e.g. Ertmer, et al., 2011; Xiao & Lucking, 2008), collaborative learning in wiki-environments in higher education raises some critical questions regarding the difficulties learners might experience when engaging in shared group processes. Recently, Kale (2013) found that some learners feel uncomfortable editing others’ ideas in the wikis. Especially in their first year of higher education, students may be rather reluctant to make changes to or comment upon work by others (De Wever, 2011).

One of the major challenges in applying wikis seems to be how to trigger and maintain productive group processes, which was one of the main questions driving this research. More specifically, the rationale for this study can be found in our earlier findings, indicating that students are often not really collaborating. Students are often working independently on specific pages, i.e. subtasks (cf. task specialization, see Hooper 1992). In this way, specific components of the wiki are developed independently by the partners and are assembled at the end to produce the final product, i.e. the wiki, while educators and learning scientists often want to create learning environments in which students are working together and participate in parallel (see Curtis & Lawson, 2001; Dillenbourg & Schneider, 1995, Henri & Rigault, 1996).
Previous findings have indicated that in order to generate such high-level collaborative activity, specific instructional support is needed (Hämäläinen & Häkkinen, 2010). Prearranging learning situations in a way that naturally triggers shared problem solving with collaboration scripts (for detailed description of scripts see, Kobbe, et al., 2007) has been introduced as a way to bring about productive group processes and shared work. Scripts are sequencing activities and assigning roles to students towards effective collaborative processes, such as effective use of resources and/or task division. Several studies have reported the positive effects of such scripts (see e.g. the review study by Fischer, et al., 2013).

The main aim of this study is to explore the impact of implementing a collaboration script for a wiki-task in higher education. The goal of the script introduced here is to enhance students’ collaboration (i.e. working together on wiki-pages) and to increase their feelings of shared responsibility for the full task. The following two research questions are put forward:

RQ1 Is there a difference between students’ experiences (with respect to collaboration and responsibility) in the scripted versus control groups?

RQ2 Is there a difference between students’ behavior in the scripted versus non-scripted groups?

It was expected that when responsibility is shared more, students will not only feel more responsible for the full wiki, but they will also show more turn-taking behavior, i.e. taking turns on developing, reviewing, and rewriting of the same wiki-pages, instead of developing, reviewing, and rewriting single pages on their own.

Method

Context and participants
181 first-year university students Educational Sciences participated in the wiki-assignment, which was a formal task embedded in a course. Students were randomly assigned to groups of five and were asked to work intensively together during a three-week period in order to create a wiki documenting the use of peer assessment in education, consisting of the following predetermined pages: (1) overview, (2) description, (3) theoretical rationale, (4) advantages, (5) disadvantages, and (6) points of attention when implementing peer assessment in educational practice. Students were provided with 10 external sources, i.e. scientific journal articles on peer assessment, but were allowed to look for extra information.

Research design

This study was a quasi-experimental study in an authentic situation. Two conditions were contrasted: a scripted and a control condition. Groups were randomly assigned either the control condition, where students were free to organize their group work, or the scripted condition, where students were instructed to follow a script. The script prompted students to start with reading two sources (each group member different ones) and to start writing a draft for one wiki-page (each group member a different one). In following steps, students were instructed to read more sources, and revise the draft of other students. The specific script will be presented in detail during the presentation.
Data sources

Students were asked to fill in a questionnaire on how they experienced the collaboration (on a scale from 0 to 10), and on the extent to which they tackled the work together (on a 7-point likert scale going from completely disagree to completely agree). As a second source of information, log files of the system were used to analyze their collaboration behavior. More specifically, the total amount of edits, the number of separate pages edited, and the amount of turn-takes were analyzed. Given the hierarchical nature of the data (i.e. students nested in groups), multilevel analyses were used to control for between group variance.

Results

Students rated the quality of their collaboration on average 7.7 on a scale from 0 to 10, with no significant differences between the scripted (M=7.4) and the non-scripted (M=8.0) condition (p=.115).

The results showed differences related to how students worked together. Firstly, students’ questionnaires indicated higher feelings of responsibility. More specifically, students in both conditions indicate that they tackled the work together, however the scripted group scored significantly higher (Ms=5.63;Mc=5.10;p<.01). Furthermore, students in the scripted group indicate more that they read all pages (Ms=6.65;Mc=5.63;p<.001), and that they felt responsible for all pages (Ms=5.69;Mc=4.65;p<.001). Additionally, students with scripts felt more that everybody was responsible (Ms=5.21;Mc=3.45;p<.001). Finally, the highest differences were found when asking students whether they helped writing to most of the pages of the wiki (Ms=6.01;Mc=3.02;p<.001).

Secondly, log file analysis showed that students in the scripted condition indeed completed more work together. When analyzing the log files, we found no significant differences (p=.388) with regard to the total number of edits between students in the scripted (M=52) and the non-scripted condition (M=48). However, students with scripts edited more distinct pages, i.e. about 8.5 compared to 6.6 (p<.001). When we take a detailed look at the five main pages of interest, we see this difference between the two conditions confirmed. Students in the scripted condition worked on average on 4.7 of the 5 pages, whereas in the non-scripted condition this is on average 2. Students are also taking significantly (p<.001) more turns when working in scripted (M=7.4) than in non-scripted groups (M=4.0).

Significance and limitations

The scientific, as well as practical, significance of this study is that when introducing a script to stimulate collaboration, students indicated that they felt more responsible and that they wrote more of the pages together, which was confirmed by log file analyses. One limitation however is that our setting did not study in detail the variations in collaboration and shared responsibility between the different learners and groups within the scripted or non-scripted settings. Therefore, further studies are needed to examine the influence of scripting for the different learners and groups.
References


Abstract: We investigated the development of a reflection framework that could be used by a Computer Based Learning Environment (CBLE) for educator self-reflection and its potential to foster pedagogical change and professional development. To inform the design of the CBLE, our first step was to generate a framework from the teaching literature covering theoretical and empirically generated models of teaching and instruction and the dimensions that together comprise the complex process of teaching. Our review of this literature provided six key dimensions, critical to the process of reflection. These dimensions are Teacher, Teaching, Learner, Learning, Content and Context. We then selected 20 participants who participated in a self-reflection study and were randomly assigned into the experimental or control group. Both groups first did a micro-teaching on a specific topic which was used as the stimulus for reflection. The experimental group was provided with the reflective framework to refer to in the self-reflection session while the control group was provided the framework after they engaged in an unguided reflection process. Our results indicated that there was a difference in the depth of self-reflection and both groups found the framework beneficial for the reflective process. As a next step, we revised our framework to include any reflective comments that were additional to those already included. This version became the foundation to develop our prototype CBLE with a view to provide the user with a well scaffolded, richer and more meaningful self-reflection. Our prototype also incorporates an Interactive Animated Pedagogical Agent (IAPA) since it has potentially social benefits to the user and can also guide the self-reflection process, similar to an external consultant. In this paper we discuss the self-reflection framework developed and its implications to the development of a CBLE with an IAPA.

Reflection on action is an inherent and necessary process for ameliorating teaching (Argyris and Schön 1974; Boud et al. 1985; Moon 1999; Schön 1983, 1987). In higher education teaching, typically, self-reflection is facilitated through a consultation process, usually mediated externally by peers, educational and faculty developers and/or consultants. This is because individuals may not be able to observe and assess their own shortcomings or may be unable to offer an honest and objective evaluation of themselves (Barber, 1990). The present project explores the potential of CBLEs in prompting reflection on action. Computer Based Learning Environments (CBLE) are currently used to foster student learning about
complex topics in science, math, computer literacy, and medical procedures (see Azevedo, Johnson, Chauncey, & Burkett, 2010; Graesser, Chipman, Haynes, & Olney, 2005; Lajoie, 2007; 2008; Leelawong & Biswas, 2008; White, Frederiksen, & Collins, 2009) and have been used effectively to scaffold self-regulated learning, metacognition, and decision making. Their successes in these contexts make them a potentially effective environment for fostering self-reflection on teaching. Our team has been exploring the use of CBLEs for self-reflection. To develop our CBLE, our first step was to design a framework with input from the teaching literature covering theoretical and empirically generated models of teaching and instruction and the dimensions that together comprise the complex process of teaching (e.g., Amundsen, Saroyan, & Frankman, 1996; Berliner, 1986; Christensen-Hughes & Mighty, 2010; Clark & Peterson, 1984; Menges & Austin, 2001; Saroyan & Amundsen, 2004; Shavelson, Webb, & Burnstein, 1984; Shepard, 2001; Shulman, 1986a; 1986b; 1987; Sternberg & Horvath, 1995; Weinstein & Mayer, 1984). Our review of the literature provided six key dimensions of the teaching and learning environment that were critical to the process of reflection. These were: Teacher, Teaching, Learner, Learning, Content and Context. Detailing each of the six dimensions we observed that in the teacher dimension, during the reflection process, the educator focuses on themselves (their philosophy, understanding, metacognition, emotion regulation, and motivation). While examining the teaching dimension, the focus is on pedagogical aspects like activating prior knowledge, quality of presentation, teaching plan, time, instructional methodology, formative assessment, and session management. In the learner dimension, the learning environment and the learner characteristics are emphasized. In the learning dimension, the attention is on new knowledge consolidation and experiential learning. The content dimension concentrates on the educator`s knowledge of the subject
matter and clarity of the task. And lastly, the context dimension centers on the physical, social, and personal learning environments where the teaching and learning takes place. This initial framework provided us with the key aspects needed to be addressed when engaging in the self-reflection process. Our next step was to revise the framework incorporating comments received in addition to what the framework already had. This version became the foundation to develop our prototype CBLE with a view to provide the user with a well-scaffolded, richer and more meaningful self-reflection. Some CBLEs use a pedagogical agent as a means of strengthening the social element for invoking cognitive processes, rendering the context more authentic to teaching and learning (Baylor & Kim, 2005). In our project, the role of the external consultant is relegated to an Interactive Animated Pedagogical Agent (IAPA). Supported by frameworks such as the Cognitive Theory of Multimedia Learning, Social Agency Theory, and the Computers as Social Actors Paradigm, the IAPAs can generate social cues through various channels (e.g., facial expressions, voice, appearance) and facilitate social interactions with learners, along the same lines as a faculty developer consultant would in a face-to-face situation. IAPAs are also perceived and treated as legitimate conversational partners that generate feelings of enjoyment in human learners as a result of casual interactions. Most importantly, however, IAPAs are not obtrusive or judgmental in their interaction with the educator and remove the potential feeling of discomfort that instructors may have in exposing or talking openly about potential weaknesses.

A total of 20 faculty participants, drawn from three different higher education institutions in a large North American metropolitan area took part in the study. They each received $100 for completing a 10-minute microteaching session followed by a self-reflection
session (the total time lasted from 40-90 minutes). The participants were video-taped. After the micro-teaching session, they were asked to view their video and think aloud as they reflected on their teaching. Participants were randomly assigned the experimental or control group. During the self-reflection session, our experimental group was provided with the reflective framework developed by our team while the control group was not provided with the framework (The control group was provided with the framework after the self-reflection session).

We elicited detailed feedback from the participants on the advantages of the reflective framework during the process of self-reflection while viewing their video. Our results indicated that both the experimental and control groups found the reflective framework beneficial for the reflective process, thus justifying the development of an environment that can systematically guide the user through the reflection process. A majority of participants commented on the ability of the framework to scaffold their reflection into considering aspects of the process that are not part of their standard pedagogical practice. In this presentation, we discuss how we have used the theoretical input and data generated from the study to design the components of our CBLE.

The implications of our study are that a CBLE intended for fostering reflection could potentially overcome some of the apparent disadvantages associated with self-reflection, namely the unwillingness to interact with another person or the inability to identify what to focus on. More importantly, it would make a pedagogical tool available to faculty to use on their own at their convenience.
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A new notion of the use of technology in students’ mathematical activities has been suggested lately, a notion based on the use of so called pedagogical agents (http://aaalab.stanford.edu/). The overall idea is to let students learn by teaching the computer, in this case, a specially created Teachable agent (TA) (Blair et.al, 2011). A student teach his TA and then assess its knowledge by asking it questions or by getting it to solve problems. The TA uses artificial intelligence techniques to generate answers based on what it was taught by the student. Depending on TA’s answer, the students can revise their agents’ knowledge, and, in this way, their own (Brophy et. al, 2011).

This study investigates the potential of TA:s in supporting students’ understanding of mathematics. The study focuses particularly on the integral, a mathematical concept that has been shown to be difficult to deal with for many students.

The first step in the study is to construct a hypothetical model of students’ problem solving trajectories – based on their solutions of integral tasks formulated with a reference to some specific misconceptions they have about the integral concept identified in previous research. The second step is to try a model through cyclic empirical testing in order to increase its usability and validity. The third step is to conduct a ”Wizard-of-Oz”-based sequences in which students teach their TA to solve integral tasks. The researcher, here acting a TA, based on a particular trajectory that student’s response is related to, comes with a feedback - a critical question that aims to cause a cognitive conflict (Tall and Vinner, 1981) in the student’s mind, in order to make him reflect and, if needed, to restructure his concept image of integrals.

Based on the model with problem solving trajectories and the ”Wizard-of-Oz”-experiments I hope to be able to suggest a prototype of TA that might support students’ understanding integrals. Another hope is that the methodological framework that have been risen in this study, will be helpful for a future development of TA:s aimed for students’ work with wide range of mathematical concepts.

References
The scaffolding paradox, supporting inquiry may not always be the best choice

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Abstract

Scaffolding the learning processes in inquiry learning is generally seen as necessary in order to achieve learning results. However, in many cases, even due to extensive scaffolding measures, it is not possible to show learning gains as a consequence of the scaffolding measures. This is despite the fact that often scaffolds do seem to have effect on the learning process.

In this paper this situation is studied by reviewing a number of studies in which scaffolding was applied in inquiry learning environments, including modelling environments. It is studied how scaffolds have been implemented and it is analyzed what these scaffolds actually mean for the process of learning. In such a way the expectations of the effects of scaffolding is reinterpreted and possible (lack of) learning effects can be understood to a greater level of detail.

In particular two aspects of scaffolding seem to arise that need further study. The first is the changes to the inquiry task that are implicit effects of many scaffolds, meaning that the scaffold may change the nature of the task in the perception of the learner. The second is the amount of learning effort that is often reduced by the scaffolds, resulting in superficial learning. As a result, learners may perform an inquiry learning task that resembles inquiry, with a product (e.g. a model or conclusion) that is of good quality without engaging in deep reasoning and hence not reaching the goals that underlie the basic ideas of inquiry learning. Hence there is a paradox: measures that seem to promote learning seem to lead to a negative effect on learning.

The paper concludes with some observations on the characteristics of scaffolds that will help identifying possible risks in potential negative effects of specific scaffolds.

Scaffolding inquiry learning

A generally accepted thesis in research in inquiry learning is that inquiry learning is difficult for students and that, as a logical consequence, learners need to be supported in the inquiry task (e.g. de Jong & van Joolingen, 1998). Scaffolding inquiry learning is seen as necessary for making this type of learning a success, and various attempts to design scaffolds (van Joolingen & de Jong, 1991a), scaffolding frameworks (Quintana et al., 2004) and integrated systems (Pedaste et al., 2013) based on various theories of inquiry learning (e.g. White & Frederiks, 1998). Whereas a number of successes have been reported (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Rutten, van Joolingen, & van der Veen, 2012), many studies in inquiry learning and modeling report successes in terms of product and process, e.g. the number of hypotheses constructed and tested (van Joolingen & de Jong, 1993), the number and order of inquiry activities performed (Manlove, Lazonder, & Jong, 2006), or the quality of models produced by the learner (Mulder, Lazonder, & de Jong, 2014). However, many studies, including the one cited here, fail to report increase of domain knowledge, or lasting improvement in inquiry skills, even though the inquiry process is heavily scaffolded.

When and why scaffolding may not work

A number of inquiry studies, including the author’s own work, was reviewed in order to search for explanations why scaffolds do or did not have the expected effect. A number of reasons for failing scaffolds can be found, including the fact that studies into inquiry learning usually cover a short period of time, in which it may be too optimistic to expect lasting effects. However, more reasons can be found for possible lack of effects. For instance, in the studies on the “hypothesis scratchpad” Van Joolingen and De Jong (1991b; 1993) it was found that the “hypothesis scratchpad” resulted in more hypotheses and more hypotheses being tested. Still no measurable learning effects were found. Looking closer at the way the scaffolds worked one may seriously question if the support for hypothesis generation actually supports genuine inquiry learning, or that it reduces the learning to meet the requirements of a form, rather than get involved in the reasoning process of creating a hypothesis that is worthwhile to test.
More specifically related to the way scaffolds are designed are the following two observations:

- Scaffolds often aim at the wrong target and change the nature of the inquiry task. In an article on the nature of inquiry learning, Windschitl et al. (Windschitl, Thompson, & Braaten, 2008) criticize the idea that there exists a single “scientific method” that can be taught in inquiry learning settings. If this is the case, we can see that many scaffolds are designed based on a more or less strict interpretation of the inquiry cycle. Whereas this may support the performance of inquiry activities within the context of a learning environment, it may not support learning suitable for the domain or context in a specific learning situation.

- Support for inquiry learning often aims at taking effort out of the hands of the learner. For instance, in a modeling task. Mulder et al. (Mulder et al., 2014) provide learners with partially solved examples and models to support model building. Where this does result in better models, it does not result in improved domain knowledge. A possible explanation for this is the fact that the scaffolds actually help learners to avoid the opportunities to learn. The learning situation may afford that learners build a product (i.e. a model) without actually learning about that product or the building process.

Scaffolds may therefore come as a support for performing a learning task in such a way that the learning no longer takes place. Interesting in this respect is a study by Sao Pedro et al. (Sao Pedro, Gobert, & Raziuddin, 2010) in which an unscaffolded group scored lower than a scaffolded group in an immediate post test, but higher on a delayed post test. This may indicate that the lack of scaffolds may have induced productive learning experiences that take some more time to have effect.

**Conclusion**

Concluding, it seems that there may be a paradox in scaffolding. By providing learners with scaffolds, we may actually remove valuable learning opportunities. In the design of scaffolds this by-effect should be taken into account. Also, one may argue that scaffolds on the cognitive level may easily be directed at avoiding moments of getting stuck, and getting the learner through the system rather than supporting to learn. Reiser (2004) also sees this distinction when distinguishing between structuring and problematizing scaffolds, where the latter provoke issues in learners’ thinking rather than helping them avoid them.

**References**


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Structuring pre-service teachers’ historical inquiry:

A script for source analysis.

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Abstract

Research suggests that inquiry learning activities are fundamental to developing students’ understanding of history. Unfortunately, the preparation of future teachers to conduct and teach inquiry activities is still largely unexplored terrain. On the one hand, there is a lack of a specific theoretical framework describing historical inquiry. On the other, research has demonstrated that historical inquiry is a complex process, and that novices generally do not engage in a critical evaluation of the information sources involved. This paper presents the development of an evidence-based theoretical framework, drawn from think-aloud protocols of 20 secondary school history teachers’ reasoning during an inquiry task. Three key activities were revealed by the data: retrieving information, evaluating information and drawing conclusions. The theoretical framework was subsequently used to design a pilot study for supporting students’ historical inquiry in the first year of teacher education, in which an external script for source analysis was tested using a control and experimental group. Preliminary results indicate that the script did not influence students’ content knowledge, but students in the experimental group did indicate that they had learned more about analyzing sources.

Research questions

A large body of research suggests that inquiry activities are fundamental to the development of students’ understanding of history (Van Drie & Van Boxtel, 2008; VanSledright & Limón, 2006). By conducting their own investigations, based on information sources describing the past (i.e. historical artifacts or secondary media), students learn that history is not merely a collection of facts and stories, but a (re)construction of the past, built from historians’ interpretations of evidence (Bain, 2000; Monte-Sano, 2010). In history, inquiry activities require students, like historians, to make careful assumptions and judgements, in order to form an account of the past (Spoehr & Spoehr, 1994). According to earlier work, such activities increase students’ understanding of disciplinary standards (Monte-Sano, 2011), as well as the content matter of history (Wiley & Voss, 1996).

Unfortunately, the preparation of future teachers to instruct historical inquiry is largely unexplored terrain. Some have argued that teachers should be capable to conduct their own investigations before they can teach historical inquiry to others (Martin & Monte-Sano, 2008). However, it is still largely unclear how the development of this competence can be supported. On the one hand, there is a lack of a specific theoretical framework describing historical inquiry. The existing frameworks in research on history education are relatively broad, and generally refer to historical reasoning in general (e.g. Van Drie & Van Boxtel, 2008). On the other hand, research has demonstrated that historical inquiry is a complex activity. In general, students do not engage in a critical evaluation of the information sources involved in a historical inquiry (Wineburg, 1991). One possible approach to support students, involves the use of collaboration scripts. Collaboration scripts support learning by prescribing activities and structuring students interaction, in order to engage students in cognitive activities they might not spontaneously demonstrate (O’Donnel, 1999). In addition, scripts appear to be particularly beneficial for inquiry activities, where students work in relatively open problem spaces and a lack of explicit scaffolding may thus result in little learning (Kollar, Fischer, & Slotta, 2007).

However, it is difficult to develop a script without a sound theoretical underpinning. The lack of a specific theoretical framework related to historical inquiry may explain why, as of yet, work on the application of technology to support historical inquiry has been scarce (e.g. Britt & Aglinskas, 2002; Saye & Brush, 2002; Van Drie, Van Boxtel, Erkens, & Kanselaar, 2005). The present paper presents the development of an evidence-based theoretical framework for historical inquiry, and demonstrates how this framework was used in the design of a pilot study to support students’ inquiry activities in the first year of history teacher education.
Method and data
The design of an intervention to support pre-service teachers during their work on a historical inquiry progressed over two distinct stages:

1. Developing a evidence-based theoretical framework. Twenty teachers, instructing history in the fourth grade of secondary education in Flanders (Belgium), participated in an exploratory study. During an individual session, each teacher was asked to solve a historical problem statement on a topic in English medieval history: The Peasants’ Revolt of 1381 (for more information, see Dobson, 1970). They were provided with fragments from four sources (i.e. two historical monographs, a wikipedia article and a medieval chronicle) to answer the following question: “Is the name of Peasants’ Revolt appropriate for the English risings in 1381?” The teachers’ inquiry activities were captured using think-aloud protocols (Van Someren, Barnard, & Sandberg, 1994): for the duration of the task, teachers were asked to verbalize everything that went through their mind.

2. Developing an external script for source analysis. Thirty-six students in the first year of a history teacher education program participated in the study. During a four-hour long activity, student dyads collaborated face-to-face on a historical inquiry in the WISE environment (Linn, Clark, & Slotta, 2003). The students were given the same task as the teachers in the exploratory study, but a fifth information source was added to the task materials (i.e. a fragment from a tv documentary). An introduction instructed students to analyze all sources, in order to write a text containing their conclusions at the end of the task. In addition, students were instructed to study a five-step strategy for evaluating sources, based upon the theoretical framework developed earlier. All sources were presented in a linear and non-random order: students had to complete work on the first source, before they could start with the next one, etc. To test the effect of a script to support source evaluation, student dyads were randomly divided over two conditions. After reading each source, dyads in the control condition received a question to note their findings about the source and its value. In the experimental condition, dyads received five separate questions asking them to note their findings relevant to the corresponding step in the five-step-strategy. All students took a pre- and post-test measuring their content knowledge, beliefs and experiences. Each answer that was entered during the task, was logged by the WISE environment. In addition, students interactions during the task were taped using digital recorders. Finally, students exam scores from the previous semester were collected.

Results
The analysis of teachers’ think-aloud protocols resulted in an comprehensive theoretical framework describing historical inquiry. Work on the analysis of the pilot study is not yet finished, but some preliminary results are available.

1. Developing a evidence-based theoretical framework. The data reveal three key activities of historical inquiry: (1) retrieving information, (2) evaluating information, and (3) drawing conclusions. Each of these activities encompasses a number of specific cognitive processes, which will be discussed in detail during the presentation.

2. Developing an external script for source analysis. With regards to content knowledge, students’ learning gain in the experimental condition (M=6.17) was greater than that of students in the control condition (M=5.22), but not statistically significant (F=0.545, p=.466). Students’ previous exam scores also did not appear to have an influence on their work on the task (F=1.45, p=.238). However, students in the experimental group (M=3.71) indicated did indicate that, compared to students in the control group (M=2.89), they had learned more about source analysis from engaging in the task (F=9.038, p=.005).

Significance
Most applications of computer-supported inquiry learning, and scripting in particular, focus on the field of science learning (e.g. physics, biology, chemistry). In comparison, social sciences such as history have received relatively little attention in inquiry-based research. Differences in students’ perceived competence for historical inquiry after completing such a task suggest that a script for source analysis may support students during historical inquiry. In addition, the newly developed theoretical framework for historical inquiry can also provide a starting point for other work in the field of history education.

References


Assessing the Design of Collaborative Mathematical Activities for Preschool Children Using Interactive Tables

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In the Swedish preschool curriculum, it is stated that children’s learning should happen through play. There is also an expectation that children will engage with ICT and be provided with situations that require them to engage with mathematical concepts. Consequently, the object of this research project is to evaluate mathematical games designed for interactive tables in regard to children’s needs and interests. Four mathematical games are analysed to determine whether they utilise the affordances of the interactive tables in ways that were likely to support preschool children’s possibilities for learning mathematical concepts and language as well as how to interact with each other. This investigation provides information about how the affordances of interactive tables can be utilised to best meet the needs of young children for future design projects.

Introduction

In Swedish preschools, children are expected engage with ICT (Utbildningsdepartementet, 2010). However, there has been little research on the affordances of different technologies and how they can be utilised with software applications, to support the simultaneously development of young children’s motor skill co-ordination, use of language to communicate, mathematical understandings. Young children also are interested in many things, some of which adults do not find interesting. Therefore, the sorts of activities and how ICT can be utilised to meet young children’s needs and interests must be considered carefully (Hvit, 2010).

Recent research on slightly older children provide promising results. Riesbeck (2013) showed that children in the first years of school can use technology to reflect on their mathematical learning. Davidsen and Georgsen (2010) found that ICT, including touch screens, support children’s collaboration on tasks. However, Ladel and Kortencamp (2012) found that the teacher’s role and the type of questions that they asked were very important for supporting German preschool children to externalise their number understandings using a multi-touch table.
Understanding the possibilities of different technologies requires identifying the relevant features, or affordances (Bower, 2008). For example, children’s use of multi-touch versus single-touch technology will affect the kinds of discussions that arise from such collaborations (Harris, et al., 2009). Therefore, the type of discussion needed to promote learning within the possibilities of a specific game should determine the technology that is used.

Interactive tables are like interactive whiteboards but are positioned as a table that young children can stand around. In our study, we explore whether four games designed for an Interactive Table have the potential to simultaneously foster preschool children’s mathematical engagement and language skills by identifying the affordances of the Interactive Table to meet the project initiators’ suggestions for what would make educationally interesting tasks.

Methodology

In the research, we used Bower’s (2008) affordance analysis of e-learning design methodology (see Figure 1). Bower’s (2008) different kinds of affordances which are identified in Table 1. Although a model for designing educational ICT tasks, in previous research (Lange & Meaney, 2012), it was used to retrospectively evaluate a teacher’s decision making in regard to developing a lesson with ICT. By working through this model, the use of different affordances of the Interactive Table in the games can be evaluated against the requirements of project initiators who identified the educational goals and suggested what would be suitable task features.

![Figure 1: The affordance analysis e-learning design methodology: matching tasks with technologies to construct e-learning designs (Bower, 2008, p. 8).](image)

The project initiators based their requirements on research about different apps for a tablet (Lange & Meaney, 2013). For a child to want to play an app, then the child needed to control it as much as possible. Apps also needed to provide enough challenge to be interesting but not so much that the child could not engage. Apps which included
something surprising in them prompted discussion. The Swedish preschool curriculum draws upon Bishop’s (1988) six mathematical activities (Utbildningsdepartementet, 2010), so a similarly broad perspective on mathematics was important in the design.

The task designers, first year university students enrolled in a gaming design course, decided on and developed the actual games, which were: Memory, Shapes, Balance and Cubes (see Figure 2). The Memory and Shapes games had two versions, a simpler and a more complex one.

![Figure 2: Memory, Shapes, Balance and Cube games for the Interactive Table.](image)

**Results**

In Table 1, we outline the affordances utilised in the different tasks. Navigation, Synthesis and Technological affordances were not utilised by any of the games. Given that these affordances are related to being able to move from one resource to another and backward and forward between these resources, it is perhaps not surprising to find that games designed for preschool children did not include them.

<table>
<thead>
<tr>
<th>Affordances</th>
<th>Memory</th>
<th>Shapes</th>
<th>Balance</th>
<th>Cube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media affordances</td>
<td>Matching different images are important component of game.</td>
<td>Images of the different shapes are key component of the game</td>
<td>Images of balance and blocks are components of game.</td>
<td>Pictures are the main media. The representations on the blocks change.</td>
</tr>
<tr>
<td>Spatial affordances</td>
<td>Cards can be turned over by touching them, but cannot be moved.</td>
<td>Shapes need to be moved to appropriate place.</td>
<td>Players move blocks onto balance baskets. Balance then adjusts accordingly.</td>
<td>N/A</td>
</tr>
<tr>
<td>Temporal affordances</td>
<td>Must be played by one person at a time.</td>
<td>The shapes can be moved in any order and simultaneously.</td>
<td>Blocks can be moved in any order simultaneously.</td>
<td>Cube faces can be changed by players simultaneously.</td>
</tr>
<tr>
<td>Navigation affordances</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Emphasis affordances</td>
<td>Turning over of cards.</td>
<td>Shapes are returned to centre when placed wrongly and place turns green when shape is placed correctly.</td>
<td>The balance is affected by the blocks put on it. When the baskets are equivalent then balance turns green.</td>
<td>N/A</td>
</tr>
<tr>
<td>Synthesis affordances</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Access-control affordances</td>
<td>Game is played by several people but only one at a time.</td>
<td>Game can be played by several people simultaneously.</td>
<td>Game is best suited to 2 children but they can operate it simultaneously.</td>
<td>Game can be played by several people simultaneously.</td>
</tr>
</tbody>
</table>
The media used in all games were visual images. Given the children’s age, instructions provided through reading, and to a lesser extent hearing, would not be appropriate. Consequently, the usability relied on the player’s intuition, but was supported by the emphasis given to particular aspects of the games. However, in the balance game, there was a system bug which meant that blocks placed near the buckets but not in the buckets affected the placement of the arms of the balance. Nevertheless, the children used their intuition to work out what was wrong. The balance and shape games involved children moving components around the table. In the Memory game, the players, one at a time, could turn the cards over by touching them. The shape game could be played one player at a time but did not have to be. The aesthetics for all the games were based on simple primary colours and uncluttered screen design.

The games met some of the requirements of the project initiators. There were links to Bishop’s mathematical activities of design (Memory, Shapes and Cube) and Measurement and Counting (Balance). Although the teachers could ask questions while the children were playing, the quick change over to a new game once the expected outcome was achieved reduced the possibilities for conversations. The Balance game when it required more than putting the same size of objects on each side, a surprising outcome, was the one which had the greatest potential for promoting conversations. The non-standard shapes in the more complex Shapes game also provided opportunities for the teacher to ask about different attributes of shapes.

**Conclusion**

The games were potentially interesting to children and provided possibilities to use and learn mathematics. The brightly-coloured layout was likely to attract children’s attention and the intuitive nature of the games meant that preschoolers would work out what to do. However, the games used only some of the affordances of Interactive Tables, so future designs could incorporate other affordances, such as the resizing of objects or recording some of the results in games such as the Balance or Cube game. These affordances could increase the possibilities for discussion between children and with the teacher as they could contribute to making the games surprising in some way.

However, it is important to observe children using the games and hear from their teachers about whether they considered that the games met the children’s needs and interests. This feedback will support us in determining what would be the best ways to ensure that children were at the centre of game designs.
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Abstract

The Expressive Agents for Symbiotic Education and Learning (EASEL) project aims to develop a new robotic agent to foster the natural and spontaneous inquisitive attitude of young children. The robot will be used to construct and validate a theoretical framework for human-robot symbiotic interaction. Our goal is to form a symbiotic relationship with an appropriate level of attachment and bonding between the robot and child for efficient and effective learning. In designing our robot we will draw heavily from existing intelligent tutoring systems (ITS). Our robot will be positioned in specific (learning) scenarios and has its own backstory. As a traveller from a distant world it does not understand our world and wants to explore it together with like-minded people; children. In our scenario the robot will collaborate with individual or small groups of children (aged 6 to 9) in inquiry learning tasks. Together they will investigate why certain materials sink or float or how a balance beam works. We will investigate child-child interactions to discover the behaviour our robot needs to exhibit to foster inquiry learning. Video recordings of children working together on collaborative inquiry tasks will be made and annotated. Key areas of interest are the questions posed by the children, reactions on observations, (eye) gaze, and emotion and affect. At present we are collecting data, during the SIG meeting we will present our first results from this investigation.

Introduction

Robots are finding their way into the classroom in different ways, as an object to study, as lesson materials for computer science or engineering courses, but also as a teaching aid, peer or tutor. The Expressive Agents for Symbiotic Educations and Learning (EASEL) project aims to develop a new robotic agent to foster the natural and spontaneous inquisitive attitude of young children.

One of the goals of the EASEL projects is to explore and develop a theoretical framework for human-robot symbiotic interaction (HRSI). We define symbiosis as: “the capacity of the robot and user(s) to mutually influence each other and alter each other’s behaviour over different time scales”. To form a symbiotic relationship, the robot must be able to identify and respond to the behaviour and emotional state of the user(s) and adapt its own behaviour accordingly.

In exploring HRSI we will construct a synthetic tutoring assistant (STA) capable of learning together with children, aged 6 to 9, in collaborative inquiry learning tasks. The STA will be used to test and validate our theoretical framework of HRSI in the context of inquiry learning.

The STA will function in a social context (Heylen, Nijholt, op den Akker, & Vissers, 2003). This context determines the available action possibilities, both in terms of mobility and expression (Krijens & Kirschner, 2001). We will model the STAs behaviour on human behaviour during collaborative inquiry tasks. In particular we are interested in questions posed, observations made, eye gazes, and (showing of) emotions.

In designing the STA, EASEL will draw heavily on existing intelligent tutoring systems (ITS) literature (de Jong, van Joolingen, Veermans, & van der Meij, 2005). ITS are designed to provide immediate and customised instruction or feedback to the user. Every ITS has at least four basic components (Nwana, 1990): an expert knowledge module, a student model module, a tutoring module, and the user interface module. The interface can take many forms, ranging from simple drop down menus for user input and printed text for output to expressive virtual agents connected to speech recognition and synthesising software. In designing our STA the step from a virtual agent to a fully embodied robot will be a crucial one.

Part of this crucial design step is the creation of a back-story for the robot (Mataric, 2014); the robot needs a reason for being there. We will introduce our robot as a traveller from a distant world. It does not understand our world and wants to explore it together with like-minded people; children.

Learning scenarios
The use-case for the robot and the audience with which it will interact need to be determined and investigated before design can commence. EASEL will have clearly defined scenarios in which the STA will be used. All scenarios will be in the domain of collaborative inquiry learning (de Jong & van Joolingen, 1998).

Learning scenarios with child-robot interactions, where the robot has specific instructional goals, will be the context in which we will explore HRSI. The scenarios will be tested in real world conditions. Our aim is to determine the aspects of HRSI most relevant in providing effective instruction and the level of human-child affect and bonding appropriate for communicating learning content in a safe and ethical manner.

In these scenarios the STA can take on different roles. It can for instance be a co-investigator collaborating with the user/learners. A different role is a more tutoring oriented stance in which the STA offers (more) instruction and support. In the context of inquiry learning, the STA could even be the subject of the inquiry, exploring the inner workings of a robot or using the robot to model different physiological processes.

The roles mentioned above lie in part on a continuum and could be combined. It is for instance possible that the STA takes on both roles as collaborator and tutor during the same session to offer the most effective support in the users learning. The STA can collaborate or only ask questions when the learner shows he has mastered or is mastering new skills, while offering more support and scaffolding during tasks experienced by the user as being difficult.

**Research questions**

A first field study will guide us in designing the STAs behaviour. Observing child-child interactions during collaborative inquiry learning tasks will help us answer our main research question in this stage of the STAs development: Which types of behavior, types and content of communication (both verbal and non-verbal), and social cues are present and important during collaborating in inquiry learning tasks? In particular:

1. What are the children's questions posed?
2. What are children's reactions of 'seeing' and describing observations?
3. What (eye) gazes do the children make?
4. What kind of emotions (e.g., facial expressions and nonverbal use of voice) do the children show?

**Method**

**Participants**
The participants are a group of 24 children, aged 6 to 9 with a 50/50 male/female distribution.

**Procedure and instruments**
The participants are recorded while working in pairs of two, both same-sex and mixed-sex couples, on a (collaborative) inquiry learning tasks. The task features basic natural phenomena and physical properties; the participants will be working with a balance beam. The constructed tasks take 20 to 30 minutes to complete depending on the age and experience of the children, resulting in up to 6 hours of video recordings.

The videorecordings are annotated, looking at the following characteristics; questions posed, reactions of 'seeing' and describing observations, (eye) gaze, and signs of emotions.

**Results**
At present we are collecting data. During the SIG meeting we will present and discuss our first results from this investigation.

**Acknowledgement**
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Claiming the promise of blended learning: New theoretical perspectives and scripting approaches

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Abstract

This paper addresses the pedagogical challenges and opportunities for blended courses from a theoretical lens of knowledge communities. Community-based approaches can help make online or blended learning more meaningful for students, introducing an epistemic shift from one of individual learning to a more socially oriented position (Slotta & Najafi, 2012). The possibilities introduced by Web 2.0 technologies have the potential to support dramatic innovations in higher education. We have developed a pedagogical model called Knowledge Community and Inquiry (Slotta & Najafi, 2012; Slotta, Tissenbaum & Lui, 2013) that can guide the design of higher education courses where students work collectively as a knowledge community to achieve targeted learning goals. The model begins with an “epistemic treatment” where students are engaged in an icebreaker activity concerning the social nature of learning in the course. From there, pedagogical “scripts” (Fischer et al, 2012) and technology environments scaffold students to work as a community, developing a knowledge base that is indexed to the targeted content domain. We have applied the KCI model in the design, enactment, critical review and iterative refinement of two undergraduate courses. In this paper, we will describe the iterative designs in terms of establishing a collective epistemology, establishing a global narrative (major project), scripted inquiry activities, and representations (knowledge base).

Introduction

This paper addresses the pedagogical challenges and opportunities for blended courses from a theoretical lens of knowledge communities. Community-based approaches can help make online or blended learning more meaningful for students, introducing an epistemic shift from one of individual learning to a more socially oriented position (Slotta & Najafi, 2012). The possibilities introduced by Web 2.0 technologies have the potential to support dramatic innovations in higher education. For example, Michael Wesch (2009) transformed his large-enrolment lecture course into a participatory game simulating world relations, where students work together to help design a two-hour simulation of the last 500 years of world history.

We have developed a pedagogical model called Knowledge Community and Inquiry (Slotta & Najafi, 2012; Slotta, Tissenbaum & Lui, 2013) that can guide the design of higher education courses where students work collectively as a knowledge community to achieve targeted learning goals. The model begins with an “epistemic treatment” where students are engaged in an icebreaker activity concerning the social nature of learning in the course. From there, pedagogical “scripts” (Fischer et al, 2012) and technology environments scaffold students to work as a community, developing a knowledge base that is indexed to the targeted content domain.

The notion of a pedagogical script introduces four key opportunities: a) providing every student with clear activity assignments at any point in time, as well as a sense of how that is part of a larger whole, b) allowing for the development of visualizations of progress and community resources, c) allowing individuals’ contributions to be
available and consequential to peers, and d) providing opportunities for a narrative of community progress.

**Method**

We have applied the KCI model in the design, enactment, critical review and iterative refinement of two undergraduate courses. The first, called “Knowledge and Communication for Development” (KCD) is concerned with the intersection of technology and international development. The second, called “Technology, Curriculum and Instruction” (TCI) aims at helping pre-service teacher candidates understand the meaningful application of technology in K-12 classrooms. Each of these courses has recently been challenged to expand and innovate, moving from a traditional face-to-face format into a more blended pedagogical format (i.e., some online and some face-to-face elements), and in the case of TCI, a tripling of student enrolment.

The KCD course was a traditional lecture-based course, culminating in a multi-stage group project where students chose a region and a topic of interest, and conducted background research to guide their development of a realistic project proposal. We redesigned the course as a hybrid model, using the final project as an organising framework for the entire course.

The TCI course addresses the need for teachers to integrate technology into lesson designs to make ideas visible, reveal conceptual models, make learning personally relevant, connect students with peers, and allow for formative assessment. Students engage in active, critical use of technologies during the course, and a major organizer is a lesson design project where students work in small groups to design a multi-day lesson that integrates one or more technologies.

**Analysis of Course Iterations**

**Establishing a Collective Epistemology**

To change the delivery mode of the course from doing something “to” the students, to having them drive their own progress, it is essential that we help them understand this fundamental shift. Students have internalized the “passive lecture” script, and need to be told that they are about to engage in a new form of collective inquiry, where they will gain from the participation of their peers. In both courses, the first lesson consisted of a short script designed to help students begin to engage in a collective epistemology, and understand their role in developing a shared knowledge base. This included a short presentation, followed by a demonstration of the course wiki, discussions of topics (including personal experiences) and an icebreaker activity (e.g., In TCI, students used Google Docs in “real time” to populate several large tables of resources for all age groups and topics of K-12 instruction).

**Establishing a Global Narrative (“major project”)**

The major project in both courses encapsulated what students should learn – both in terms of theoretical insights and critical skills related to analysis and presentation – allowing it to serve as a pedagogical index for all prior activities. For example, in KCD we generated a list of skills that students would need for their final project, and made sure to provide safe opportunities for students to practice these skills with peer- and instructor-feedback during the course.

The persistent knowledge base generated by the students during all the in-class and between-class activities was designed to support their creative inquiry around the major project. This helped motivate students to contribute, and enabled them to see how various activities fit into the narrative arc of the course.

**Scripted Inquiry Activities**

For each course, we developed a sequence of knowledge building and inquiry activities, alternating between small group and whole class interactions. For example, in KCD, groups came up with arguments for or against statements, found definitions and contextualized them in terms of previous readings. They shared these with the class, and went back to the small groups to critique or build on the work of other groups. This form of interactive in-class work gave students a chance to share their understanding with peers, provided opportunities for the instructor to model critical thinking, and provided immediate personalised feedback. Knowledge Base/Representations

In each course, students collaboratively generated a knowledge base that was indexed to the learning goals of the
course. In TCI, this knowledge base persisted across course offerings, with students from the current cohort building on what earlier cohorts had generated. In KCD, students were grouped according to themes, and chose research topics within those themes. Only after spending several weeks collaborating with other groups on filling in a wiki page template did the individual groups begin defining their project focus. The ideas generated during and between classes were all captured, supporting both the final project, and the open-book exam.

Our presentation

Our presentation will illustrate the two courses with examples of student work and community progress. We will present a full analysis of each course in terms of KCI principles, and also describe our revisions to the course designs based on analysis (i.e., in a design research progression). Finally, we will discuss the scripting and orchestration of both courses according to recent frameworks offered by Fischer (2013) and Dillenbourg (2013).

References


Critiquing Peer Ideas during Technology-Enhanced Science Inquiry Learning

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Abstract
Generating ideas is an important part of inquiry learning. As students investigate scientific phenomena, they ask questions, test assumptions, make observations and collect evidence to generate ideas. Sharing those ideas and comparing them with peer-generated ideas allows students to reflect upon and to refine their own ideas. However, the mere sharing of ideas might not be sufficient. Based on the Knowledge Integration framework, it is important to support students in distinguishing between normative and non-normative ideas to develop an integrated understanding. Students also need to be scaffolded to compare and distinguish between peer ideas with their own ideas. This especially is the case when learning about abstract concepts, such as energy. In this study we explored the value of critique to support students in distinguishing between ideas about energy. In a 4-day web-based inquiry unit on photosynthesis, we incorporated 5 steps that use the Idea Manager tool to scaffold students’ idea generation and sharing. In total, 124 students from five middle school classes were randomly assigned to one of two conditions where students either chose ideas they disagreed with (Critique) or agreed with (Agree). Open response and multiple choice items from embedded assessments and pre- and posttests, as well as students’ revisions to, and the quality of, their ideas are currently being analyzed. Preliminary findings from a subsample showed no differences between conditions on the post-test. Initial analyses of students’ work with the Idea Manager reveal that in the Critique condition, students suggested revisions only if they deemed peer ideas to be incorrect. In the Agree condition, students tended to restate peer ideas, and to make no suggestions for revision. Findings from this study will have implications for the role of critique and the design of technology-enhanced instruction during the generation and sharing of ideas in science inquiry learning.

Introduction
Generating artifacts such as explanations (Ryoo & Linn, 2014, Chi, 2000), concept maps (Schwendimann, 2013) or ideas (Matuk & Linn, 2014) have been found to be beneficial for understanding scientific concepts and processes. Yet, students need to be supported to distinguish information in order to form a normative, integrated understanding. In this study, we investigated the value of students sharing ideas through a web-based, curriculum-integrated tool, and explored instructional designs for helping students distinguish ideas through critique.

Energy is a crucial concept of science to understand and explain scientific phenomena across disciplines. Students need to understand underlying energy mechanisms to gain deep understanding. One central mechanism is energy transformation that energy is transferred from one type of energy into another type (Liu & McKeough, 2005). In middle school, energy transformation is for instance introduced in the context of plant growth and climate change. However, it can be difficult for students to link everyday and formal conceptions of energy. Dynamic visualizations and drawing activities provide effective means to engage students in thinking about the flow of energy and energy transformation. Although visualizations can help students confront their initial ideas, students still only generate fragmented ideas (Linn, Chang, Chiu, Zhang, & McElhaney, 2010). Misconceptions of energy often remain because visualizations alone are not sufficient to help students connect ideas in a normative way. Students need to be supported to make distinctions between their own and newly encountered ideas (Linn & Eylon, 2006). Moreover, instruction that takes advantage of the classroom as a community of learners can allow students to use and build upon the ideas of their peers to gain an integrated understanding (Brown & Campione, 1996; Matuk & Linn, 2014).

Theoretical background
Generating and sharing ideas are aligned with the Knowledge Integration framework (KI, Linn & Eylon, 2011).
However students need to be supported to benefit from generating and sharing ideas. KI specifies effective instruction to include eliciting ideas, adding ideas, distinguishing among ideas and reflecting on ideas. Critique can be an effective instructional strategy to support distinguishing and reflecting ideas (Schwendimann, 2013). Critiquing peer ideas can help students to relate peer ideas back to their own ideas and revise their ideas. This study explores the value of critique for promoting knowledge integration, specifically distinguishing and reflecting ideas, by exploring a critique activity within a technology-enhanced science inquiry unit. We examine scaffolds for guiding students to critique peer ideas and to contrast those ideas to their own ideas. In this study, we investigate whether students benefit more from critiquing ideas they disagree with, than from exploring ideas they agree with.

Study design
We redesigned the Photosynthesis unit, available within the Web-based Inquiry Science Environment (WISE, Linn, Davis, & Bell, 2004), to focus students’ thinking around the advantages of green roofs. In the unit, students explore the concept of energy transformation through dynamic visualizations and drawing activities that compare sunlight energy hitting an asphalt roof vs. a roof covered in plants (i.e., a green roof). Our redesign of the unit added idea generation and sharing activities according to the KI framework. We used the Idea Manager, a tool within WISE, to scaffold students during idea generation and sharing (Matuk & Linn, 2014). Five Idea Manager steps were implemented throughout the unit to guide students from generating initial ideas, sharing ideas, selecting peer-generated ideas, comparing these to their own ideas and finally writing an explanation that integrates their ideas.

![Figure 1. Ideas Manager with Activity Steps](image)

Altogether, 124 sixth grade students from five classes, taught by the same teacher were randomly assigned to one of two conditions: Critique or Agree. Critique students were asked in the Idea Manager step to choose ideas from their classmates, which they disagreed with. They were then asked to explain why they disagreed, and how they would revise that idea. Agree students were asked to choose an idea they agreed with and then prompted to explain how this idea added evidence to their own ideas. Students worked on the unit for four 50-minute class lessons on consecutive school days. Additionally they spent two class lessons completing a pre and posttest (described below).

Analysis
Measures included a pre- and posttest, as well as students’ work with the Idea Manager responses during the idea generation and sharing activities. The pre- and posttest included eight multiple choice and eight open response items designed to assess students’ knowledge integration (Liu, Lee, Hofstetter & Linn, 2008). Idea Manager work included students’ generated ideas, shared ideas, revised ideas (their own as well as peer-generated) and explanations during and after idea-sharing. The pre- and posttests, as well as the Idea Manager work, were analyzed with a KI rubric (Table 1)
adapted from rubrics of earlier versions of the unit (Ryoo & Linn, 2014).

Table 1: Rubric based on the KI framework

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Student Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Irrelevant)</td>
<td>No answer or irrelevant answers</td>
<td>I guessed</td>
</tr>
<tr>
<td>2 (No Link)</td>
<td>Non-normative ideas or links</td>
<td>The energy is trapped so it does not get lost in the atmosphere or in space</td>
</tr>
<tr>
<td>3 (Partial Link)</td>
<td>One relevant and normative idea</td>
<td>Energy from the sun light is absorbed by the plant</td>
</tr>
<tr>
<td>4 (Full Link)</td>
<td>Scientifically valid and fully elaborated link between two relevant and normative ideas</td>
<td>When sunlight reaches a green roofs, light energy is transformed into chemical energy</td>
</tr>
<tr>
<td>5 (Complex Link)</td>
<td>At least two links among three or more relevant and normative ideas</td>
<td>Sunlight hits a dark roof, is absorbed by the roof, is converted into heat energy, is emitted as heat into the city/air/atmosphere</td>
</tr>
</tbody>
</table>

Preliminary findings
We report on a subsample of 50 students and three pre-and posttest items. Preliminary differences on the selected posttest items showed no significant effect between the Critique condition (M = 3.49, SD = 0.70, SE = 0.15) and the Agree condition (M = 3.32, SD = 0.55, SE = 0.11); t (105) = -.931, p = .366). This suggests that students learned in both conditions similarly well. In-depth analyses of the embedded items and quality of ideas will clarify potential differences in students’ understanding between the two conditions. Initial analysis of students’ work with the Idea Manager shows that students in the Critique condition were hesitant to critique peer ideas. Often, students stated that all ideas were correct as is, providing no suggestion for revision. However, when students indicated that peer ideas were incorrect and subject to critique, they also included suggestions for revision. In the Agree condition, students tended to restate the ideas they selected as agreeable, and made no suggestions for revision. It may be that when new ideas are framed as subject to critique, students are encouraged to make distinctions. The KI framework predicts that this can have positive effects on students’ understanding. Further analyses are underway to investigate whether this trend persists, and the impacts it might have on student learning. Results will be presented at the conference.

References
learning (CSCL). Madison, WI.