UNIVERSITEIT GENT

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

The impact of "computer-supported collaborative inquiry" for science learning in secondary education

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Proefschrift ingediend tot het behalen van de academische graad van Doctor in de Pedagogische Wetenschappen

2015

VOORWOORD

Mijn proefschrift ligt er en daar ben ik fier op. Heel veel mensen hebben mij de voorbije jaren hierbij bijgestaan en daarom uit ik graag een woord van dank.

Mijn promotor, prof. dr. Tammy Schellens. Dankjewel om in mij jouw assistente te zien en mij de kans te geven te starten aan dit doctoraat. Je liet mij in alle vrijheid mijn onderzoeksinteresses volgen, maar stuurde steeds kritisch bij waar nodig. Dankjewel om me binnen te loodsen in jullie netwerk. Mijn eerste conferentie was weinig representatief, maar was er wel eentje om nooit te vergeten!

Prof. dr. Bram De Wever. Dankjewel dat ik altijd mocht aankloppen met vragen en twijfels, ik kwam steeds vol goeie moed terug buiten. Ook op conferenties was jij altijd onze trouwe gids, waarvoor dank.

Mijn begeleidingscommissie, prof. dr. Paul Kirschner, prof. dr. Wouter van Joolingen en prof. dr. Jim Slotta, dankjewel voor jullie constructieve feedback en wijze raad bij het nemen van beslissingen tijdens mijn doctoraatsproces. Ik heb mooie herinneringen aan onze bijeenkomsten, zowel in Gent als op de CSCL en ICLS congressen. Jim, special thanks to you for introducing me to WISE and the Knowledge Integration approach. You made it possible to do my visiting sholarship at UC Berkeley and to get acquainted with the Technology-Enhanced Learning in Science Research Community.

Collega's van de vakgroep onderwijskunde, ik heb vaak geboft over wat een leerrijke én fijne werkomgeving wij wel hebben. Ik blik met een glimlach terug op de vakgroepuitstappen, de traktaties na de vakgroepraden, de congressen, maar ook de dagelijkse gezellige middaglunches, dankjewel allemaal! Toch zijn er ook een aantal collega's die ik speciaal wil vernoemen. Sabrina, door met jou de eerste jaren een bureau te delen, voelde ik me meteen thuis. Dankjewel Ellen voor de productieve en fijne samenwerking, peer assessment werd ons gezamenlijk zijproject dat Tijs nu kan verderzetten. Hilde, Emme, Fien, Jessie, Cindy, Tijs en Lore of "de Begijntjes", bedankt voor de leuke tijden in ons microklimaat. En ten slotte, Tijs, Lore en Britt waarmee ik het nieuwe eiland deel, bedankt voor de schouderklopjes, de frietjes en het nalezen tijdens mijn eindsprint; ik kijk ernaar uit om jullie nu terug wat meer bij te staan!

Alle leerkrachten, leerlingen en ook alle masterstudenten onderwijstechnologie die het de voorbije jaren mogelijk maakten dit onderzoek te realiseren, dankjewel! Zonder jullie stond ik nergens.

Mijn lieve familie en vrienden, dankjewel om ons meisje op te vangen wanneer ik er niet kon zijn voor haar en dankjewel voor het warme nest tijdens de weekends. Vrienden, jullie heb ik de laatste tijd wat verwaarloosd, maar laat die feestjes nu maar komen, ik ben er terug klaar voor.

Dries, zonder jou was ik waarschijnlijk nooit aan een doctoraat begonnen, jij gaf me de nodige boosts, maar je was ook mijn kritisch lief, die durfde zeggen wanneer het vijf voor twaalf was. Clara'tje, dankjewel om er te zijn, want jij maakt me altijd blij!

Gent, februari 2015
Annelies

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General introduction

Abstract

The present dissertation starts with a general overview of the research issues and the main concepts that are presented in Chapters 2 to 6. After a general introduction, the main research objectives challenged in this dissertation are outlined. The introduction concludes with an overview of the methodological approaches applied in each study and gives an overview of the different chapters included in this dissertation.

Introduction

A basic understanding of science is considered a necessary skill for every European citizen. Concerns about low student performance in basic skills, as revealed by international surveys, led to the adoption in 2009 of an EU-wide benchmark which states that "by 2020 the share of 15-year-olds with insufficient abilities in reading, mathematics and science should be less than 15 %" (EACEA/Eurydice, 2011). In 2006 the Program for International Student Assessment (PISA) (Organization for Economic Co-operation and Development [OECD], 2007) focused for the first time on science competences and revealed that Flanders belongs to the group of OECD countries which achieved high results for scientific literacy. Moreover, based on the PISA 2009 database regarding student achievement in science it could be stated that next to Estonia, Poland and Finland, the Flemish community had already achieved this benchmark (i.e. the number of low-achievers in science to be significantly lower than 15 %). The most recent PISA 2012 findings however revealed a significant decrease in scientific literacy compared to the results in 2006, whereas the mean scientific literacy across the OECD countries significantly improved (PISA, 2012). This decrease in Flanders is due to a significantly improved amount of students with insufficient abilities and consequently Flanders does not achieve the EU benchmark anymore. This is alarming since these students are considered as low-achievers with limited scientific knowledge which may hinder full participation in society and economy (Woodgate, Stanton Fraser, & Crellin, 2007).

Next to this, it is also worrying that in comparison with the 15-year-old students in the average OECD country, fewer Flemish students reported that they were motivated to learn science, and only an absolute minority thought that they would work with science later on (De Meyer, 2008). This is confirmed by the Flemish educational board reporting that the number of students who consider taking up studies and careers in science is at a low level, especially for female students (VRWI, 2012). Recent research findings emanating from a range of countries demonstrate that gender equity in science education is still a cause for concern (Machina & Gokhale, 2010; Osborne, Simon, & Collins, 2003; Taasoobshirazi & Carr, 2008). Although we are experiencing a steady growth in the number of female students enrolling in university (Machina & Gokhale, 2010; Meulders, Plasman, & Rigo, 2009; Pelleriaux, 2000), females are still under-represented in faculties of sciences.

In this regard, important questions to address considering an increasing recognition of the importance and economic utility of scientific knowledge in an industrialized society are: How is it possible to raise the motivation of students, to increase their interest in science, and at the same time, to increase achievement levels and obtain the 21st century skills that aim to prepare students for complex professional tasks in increasingly complex workplaces? And can school science be successful in reaching all pupils, regardless of gender and achievement level, as well as educating future scientists?

When we question what can be done to eliminate young people's lack of interest in science and to decrease gaps in science participation, the literature strongly suggests a focus on the formation of positive attitudes toward science as a key element (Osborne et al., 2003). A crucial factor that affects students' attitudes toward science is the way science is educated and taught in classrooms (Osborne et al., 2003). Unfortunately, much of what is going on in contemporary science classrooms is not particularly attractive to students. Whereas adolescents in the 21st century are immersed in a world where they are connected to their peers, to technology, and to the web-content they are interested in, they often enter science classrooms in which they are disconnected from their peers and from the tools they regularly employ for informal learning, and are often required to consume, complete, and replicate given knowledge (d'Apollonia, 2010). As a consequence, they are prone to consider science as boring, difficult and not engaging and irrelevant for their own life (Flemish Government., 2006; Stark & Gray, 1999). Introducing context-based and inquiry-based science content into the curriculum and supporting this by technologies can transform science teaching into an engaging learning experience, since these innovative approaches appear to be helpful in maintaining positive attitudes toward science and toward science instruction (Slotta & Linn, 2009). Next to that, context- and inquiry-based science instruction is supported by national standards and educational policy in an attempt to make science accessible and interesting to high- and low-achievers in science and to rectify the gender imbalance in science education (OECD, 2009; VRWI, 2012). More specifically, computer-supported collaborative inquiry learning (CSCiL) is a promising approach for science education since learning with technology and the internet seems to be motivating for youngsters on the one hand and students need to develop a fluency with information technologies in order to succeed in lifelong learning in the 21st Century on the other hand (Wallace, Kupperman, Krajcik, & Soloway, 2000).

Yet, although CSCiL is highly promoted for science education, this kind of learning is much more challenging compared to traditional education from both the learner's and teacher's perspective. Regarding the learner's perspective, problem-solving environments rely heavily on students' ownership over their learning and depend on students' self-regulated investigations.

Yet, students often lack the regulation skills to plan, monitor and evaluate their inquiry (Azevedo, 2005; Brand-Gruwel, Wopereis, & Walraven, 2009; Kuiper, Volman, & Terwel, 2009; Raes, Schellens, De Wever, & Vanderhoven, 2012). This means that in inquiry classes, students may encounter challenges when not adequately supported, particularly when they do not have sufficient prior knowledge (Kirschner, Sweller, & Clark, 2006). In this regard, support and guidance of inquiry is crucial to take full advantage of this kind of learning. Yet, regarding the teacher's perspective the skills needed to scaffold students' inquiry learning in technology-rich classrooms are proved to be substantially different from those emphasized in traditional classrooms (Kim & Hannafin, 2011) and teachers are often not well trained in embedding this innovative and student-centered form of learning in their curriculum.

This brings us to three main challenges of this dissertation: (1) What can be achieved by implementing CSCiL in secondary science education regarding students' knowledge achievement, their inquiry skills, and their motivation for science? (2) For whom is this learning approach suitable and beneficial? and (3) How should this learning approach be guided and supported to benefit all students?

Conceptual framework

Computer-supportive collaborative inquiry learning (CSCiL)

Inquiry-oriented science instruction has been characterized in a variety of ways over the past two decades and promoted from a variety of perspectives (DeBoer, 2000; Krajcik et al., 1998; Rakow, 1985; White & Frederiksen, 1998). A universal definition for scientific inquiry remains elusive; however, core features are evident in various definitions across the literature, including questioning, generating hypotheses, experimenting, designing, planning, predicting, visualizing, observing, data collection, analyzing, interpreting, and explaining (Donnelly, Linn, & Ludvigsen, 2014). In general it can be assumed that inquiry-based learning is a student-centered, active learning approach, which stimulates students to get involved in a social, active, engaged, and constructive learning process, as opposed to more traditional approaches, which tend to emphasize the memorizing of factual information. Inquiry-based learning is particularly well-suited for collaborative learning environments and team projects (Gillies, 2007). At the same time, information and computer technologies are receiving increased attention because of their potential to support new forms of (collaborative) inquiry (Chang, Sung, & Lee, 2003).

Consequently, these innovative learning and classroom strategies are reflected in several learning environments world-widely developed in the context of Computer-Supported Collaborative Learning (CSCL), such as BGuILE (Reiser et al., 2001), Co-LAB (van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005), nQuire (Anastopoulou et al., 2012) and WISE (Slotta & Linn, 2009). These inquiry learning environments are presented as arguably, more interesting and motivational approaches for secondary science education. Within the present research project the Web-based Inquiry Science Environment (WISE) as depicted in Figure 1 is used in the context of this dissertation.

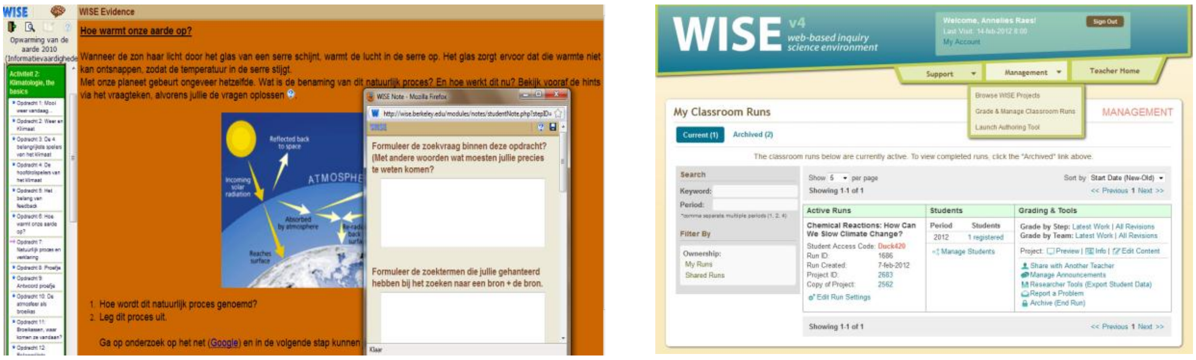

Figure 1. Screenshots of the WISE learning environment from the learner's (left) and teacher's perspective (right)

WISE is a powerful inquiry learning environment for designing and implementing inquiry practices (http://wise.berkeley.edu) according to the Knowledge Integration framework. WISE has been created and maintained by the Technology-Enhanced Learning in Science Center which is funded by the National Science Foundation. TELS is headquartered at the University of California, Berkeley, and is directed by Professor Marcia Linn. The knowledge integration framework is built around four design principles: (1) making learning accessible; that is exploring meaningful and authentic scientific contexts, (2) making learning visible by using powerful visualizations, (3) learning from each other, and (4) developing autonomous, metacognitive learning practices that involve students in the lifelong process of integrating, distinguishing, and sorting out their ideas to develop a more coherent or convincing argument based on evidence (Donnelly et al., 2014; Linn & Eylon, 2011; Slotta & Linn, 2009).

CSCL in general refers to situations in which computer technology plays a significant role in shaping the collaboration (Goodyear, Jones, & Thompson, 2014). CSCL can involve learners who are working at a distance from each other and the computer technology is their primary means of interacting, but the CSCL concept is also used to describe situations in which learners are co-present, as long as the technology plays a significant role in shaping the nature of their interactions with each other and supporting their collaborative activities. In the context of this dissertation CSCL refers to the latter; that is, learning that takes place face to face.

Objectives in science education

Previous research has indicated that participation in computer-supported collaborative inquiry learning can provide students with the opportunity to achieve three interrelated learning objectives in science: (1) knowledge acquisition (Lee, Linn, Varma, & Liu, 2010; Slotta & Linn, 2009), (2) the development of general inquiry abilities (i.e. the skills of formulating and refining researchable questions, generating hypotheses, planning and conducting investigations, and reporting and applying results) (Edelson, Gordin, & Pea, 1999) and the acquisition of specific investigation skills (i.e. information problem solving: searching for evidence and synthesis of sources) (Wiley et al., 2009), and (3) the generation of positive attitudes and motivation toward science (Kyle, Bonnstetter, McCloskey, & Fults, 1985; Rakow, 1985).

Knowledge acquisition in science

With regard to the first learning objective it can be stated that although skills and attitudes are becoming more and more important, knowledge acquisition remains of crucial importance. In the most general sense, the contemporary view of learning is that people construct new knowledge and understandings based on what they already know and believe (see e.g., Vygotsky, 1978). Constructivism has a long history in the context of science education and generates the idea that learners form their own understanding of certain natural phenomena which, however, most often conflicts with real scientific understanding (Anderson, 2007; EACEA/Eurydice, 2011). A logical extension of the contemporary view that new knowledge must be constructed from existing knowledge is that teachers need to pay attention to the incomplete understandings, the misconceptions, and the naive renditions of concepts that learners bring with them to a given subject. Teachers then need to build on these ideas in ways that help each student achieve a more mature understanding (Bransford et al., 1999; Harlen, 2009 in EACEA/Eurydice, 2011; Linn & Eylon, 2011). There is a great deal of evidence that learning is enhanced when teachers pay attention to the knowledge and beliefs that learners bring to a learning task, use this knowledge as a starting point for new instruction, and monitor students' changing conceptions as instruction proceeds.

In line with this learning theory the Knowledge Integration (KI) approach has been conceptualized by Slotta and Linn (2009). KI regards knowledge acquisition as a process of integrating new and existing ideas. The goal of instruction is therefore to support learners by eliciting their ideas, and guiding them to distinguish these from new information. Within inquiry practices learners incorporate new ideas into a body of existing ideas since the design of the activities is based on the following instructional pattern: "Elicit ideas – Add new ideas – Distinguish among ideas – Reflect on and integrate ideas."

Next to this, there are arguments in support of an integrated (versus separate-subject) science teaching approach. First, it can be stressed that traditional discipline boundaries do not reflect contemporary needs, and scientific research itself is becoming increasingly integrated and interlinked (Atkin, 1998). Second, making connections between different disciplines is seen as a process leading to new ways of thinking and knowledge that forms the "big picture" and deeper understanding (Czerniak, 2007).

Inquiry skills and collaborative (information) problem solving

All individuals, whether they are practicing scientists or not, need a level of science literacy that allows them to participate in public discourse and debate about current issues and controversies in science (Wiley et al., 2009). Yet, what students learn in science class is often the product of scientific studies, not the process. But by presenting science as facts and not as a research process, students do not get a full appreciation that science is about doing inquiry, reasoning from evidence and constructive integration across information sources. In that sense, the development of such skills should also form part of the teaching content in science classrooms.

Introducing CSCiL in science classrooms aims at the development of general inquiry abilities and the acquisition of specific problem solving skills. Generally speaking, science inquiry involves five essential features (Bransford et al., 2000): (1) engaging students in scientifically oriented questions, (2) using evidence to respond to questions, (3) formulating explanations on the basis of evidence, (4) connecting explanations to scientific knowledge, and (5) communicating and justifying explanations. Moreover, science inquiry on the web can be seen as a specific case of inquiry learning (Wiley et al., 2009) which provides a special opportunity to investigate the process of search, selection, evaluation, comparison, synthesis, and integration of ideas from multiple sources of information for the purposes of producing explanations (Driver, Newton, & Osborne, 2000; Wiley et al., 2009).

Moreover, while problem solving as defined for PISA 2012 (OECD, 2010) relates to individuals working alone on resolving problem situations, in the new framework in preparation of PISA 2015 (OECD, 2013a), the aspect of collaboration is the most salient addition to previous versions of the domain of problem solving in PISA (see OECD, 2003 and OECD, 2013b). Collaborative Problem Solving is nowadays seen as a critical and necessary skill across educational settings and in the workforce. Students emerging from schools into the workforce and public life will be expected to have collaborative problem solving skills as well as the ability to perform that collaboration using appropriate technology.

Positive attitudes and motivation for science learning

A third key objective is to encourage more students to study science or to participate in scientific discourse in response to the generally observed decline in motivation for science learning from the age of 11 years on (Osborne et al. , 2003). Previous research suggests that students' attitudes toward science, achievement, and career aspirations are closely related (Lee & Burkam, 1996; Park, Khan, & Petrina, 2008; Simpson & Oliver, 1990). In this respect, attitudes toward science need to be taken into account when questioning young people's interest in science and the current gaps in performance and participation in science (Zusho, Pintrich, & Coppola, 2003). Attitudes toward science do not consist of a single unitary construct, but rather of a large number of sub constructs all of which contribute in varying proportions toward an individual's attitudes toward science (Osborne et al., 2003). The sub constructs often mentioned with regard to the affective domain in science education are self-efficacy, self-concept, interest in science, enjoyment of science, instrumental motivation to learn science, career intentions, awareness of environmental issues, optimism regarding environmental issues, and responsibility for sustainable development (OECD, 2007). In this dissertation, however, we needed to limit the focus on the motivation for science learning, in the sense of what students drive or move to do something (Ryan & Deci, 2000). Since motivation is not considered to be a general trait, but assumed to be situated and changeable as a function of instruction and activities that take place in a classroom (Bonney, Kempler, Zusho, Coppola, & Pintrich, 2005), improving science education has been high on the political agenda of many European and worldwide countries.

It is found that connecting science to everyday life and engaging students in topics and activities with personal and future relevance is crucial, since such connections can trigger changes in students' motivational structure toward more intrinsic orientations (Nieswandt & Shanahan, 2008). Additional research clearly shows that by reflecting, applying ideas, and collaborating with peers, students develop a sense of the relevance of science (Bransford et al., 2000). Consequently, the influence of the classroom environment and the quality of teaching are revealed as significant determinants of student views of the subject of science.

Student and class characteristics associated with science performance

Because education faces a challenging task in providing adequate instruction to meet the needs of a diversity of students (EACEA/Eurydice, 2011), the focus is on whether CSCiL could be beneficial for all students, keeping in mind three important student and class characteristics that is gender, achievement level and tracking. Moreover, not all learners are alike in their need for instruction and various aptitude-by-treatment interactions (i.e., different groups of learners might benefit from different instructional approaches) might occur (Cronbach & Snow, 1977). Therefore, also particular student characteristics might influence an intervention's effectiveness.

Gender differences

Recent research findings emanating from a range of countries demonstrate that gender equity in participation in science education is a cause for concern (Machina & Gokhale, 2010; Osborne et al., 2003; Taasoobshirazi & Carr, 2008). The Flemish educational board reported that the number of students who consider taking up studies and careers in science is at a low level, especially for female students (VRWI, 2012).

Many attempts have been made to explain this and to solve this problem. A possible explanation could be gender differences in science achievement; however, no strong evidence can be found for a gender gap in science achievement and the results are often contrasting. Although (meta-) analyses of performance on standardized tests regularly report gender differences in favor of males in science achievement tests (e.g. Hedges & Nowell, 1995) and there is the popular stereotype that males excel in science (Halpern, Straight, & Stephenson, 2011), a recent meta-analysis on gender differences in academic achievement as measured by teacher-assigned school marks indicated a female advantage as a common finding in educational research. Next to science achievement results, biological and sociocultural factors can be proposed to explain gender issues. According to Kenney-Benson, Pomerantz, and Ryan (2006) the learning style of females tends to emphasize mastery – i.e. pursuing work in the hope of understanding the material – over performance – i.e. focus on marks – in task completion, whereas males tend to show the reverse emphasis. In line with this, a meta-analysis conducted by Else-Quest, Hyde, Goldsmith, and Van Hulle (2006) indicated a female advantage in effortful control and a male advantage in surgency. These subjective factors cannot be overlooked since gender differences in class behavior could affect teachers' evaluation of their students, potentially leading to sex-biased treatment and self-fulfilling prophecies (Voyer & Voyer, 2014).

Consequently, a challenging question is how gender equity can be achieved in science education when implementing CSCiL.

Although some research report gender issues in technology, i.e. women's level of anxiety and their lack of confidence (Durndell, Glissov, & Siann, 1995; Okebukola & Benwoda, 1993) in contrast with male dominance (Prinsen, Volman, & Terwel, 2007), a research study of Mayer-Smith, Pedretti, and Woodrow (2000) has found that women can enjoy and be successful at learning science in technology enriched environments. Next to that, evidence is found in a meta-analysis of 61 studies on the effects of context-based science education on students aged 11-18 which stated that gender differences in attitude "narrow" as a result of context-based interventions (Bennett, Lubben, & Hogarth, 2007). Additionally, context-based courses appear to have a positive impact on overall performance, and on girls' performance relative to that of boys (Murphy & Whitelegg, 2006). However, in the area of knowledge integration research particularly, which combines context-based instruction within a technology-enhanced learning environment no systematic research is found examining its effects on girls compared to boys.

Achievement levels in science

As previously noted, all European Union member states have a political commitment to reduce the proportion of low-achievers or students lacking basic skills in science. A challenging question is which teaching method is successful in reaching all pupils, regardless of achievement level.

Besides the promising findings regarding inquiry based learning, there is a prevalent conception that higher-order learning goals such as knowledge-building activities (Chan & Lee, 2007) which are in line with knowledge integration (Slotta & Linn, 2009) are only suitable for certain students, especially those with higher cognitive abilities. This may be based on one of the principles of Aptitude-Treatment-Interaction (Cronbach & Snow, 1977), that highly structured instructional environments tend to be most successful with students of lower ability and that low structure environments on the other hand may result in better learning for high ability students. Moreover, if students are reluctant or resistant to answer teachers' questions because they do not know the answer, how teachers interpret this reticence or resistance has consequences for how intelligent or academically capable they judge students and their instructional approaches toward them. Certain beliefs may then become a self-fulfilling prophecy, because teachers would tend to avoid the use of higher-order thinking activities with low prior knowledge or low-achieving students who would be “stuck” at learning that emphasizes memorization and methods of drill and practice (Zohar, Degani, & Vaaknin, 2001; Zohar & Dori, 2003). Previous research, however, found that science curricula emphasizing higher-order thinking skills were effective for both high- and low-achieving students (Chan & Lee, 2007; So, Seah, & Toh-Heng, 2010; Zohar & Dori, 2003). Moreover, in one of their four studies, Zohar and Dori (2003) found that the net achievement gain in inquiry science teaching was significantly higher for those with lower abilities than higher achievers. Also for educationally disadvantaged students the ambitious instructional context represented by inquiry science teaching has unique opportunities when appropriate scaffolding is provided (Palincsar, Magnusson, Collins, & Cutter, 2001; White & Frederiksen, 1998).

Differentially tracked students

In many educational systems, including the Flemish system, students are separated into different academic tracks that consist of a package of courses each with a focus on e.g. languages, economics, and/or science. Dividing students into different academic tracks (further referred to as tracking) happens primarily on the basis of their proficiency as determined by previous course grades, yet tracking also occurs by student and parent choice (Pickens & Eick, 2009). Studies have shown that differences in educator expectations for student science learning, justified by tracking, also result in different quality of teaching science (Nieswandt & Shanahan, 2008; Pickens & Eick, 2009). Students in the science classes most often receive instruction emphasizing scientific reasoning and inquiry-based instruction (Haury & Milbourne, 1999), whereas general class students receive less challenging instruction, and are subsequently less motivated to learn science (Oakes, 2005).

Niu and van Aalst (2005) examined the extent to which knowledge building approaches are beneficial to regular and honors classes in Canada. In their study of high school students using “knowledge forum”, it was found that while the students in the honors class did better than those in the regular class, the effect was more influenced by within-class differences than between-class differences. In some of the qualitative measures, the regular students outperformed the honors students.

Classroom implementation of CSCiL

Even though the potential of CSCiL to positively impact science learning has been proved in previous studies, enacting inquiry has met considerable difficulties within authentic school contexts (Donnelly et al., 2014). Students and teachers are often unsure of the new roles and responsibilities that inquiry requires (van der Valk & de Jong, 2009) and teachers often lack the experience, content knowledge, and pedagogical strategies needed to scaffold students’ inquiry learning in technology-rich classrooms, which are substantially different from traditional classrooms as shown in Figure 2 (Kim & Hannafin, 2011).

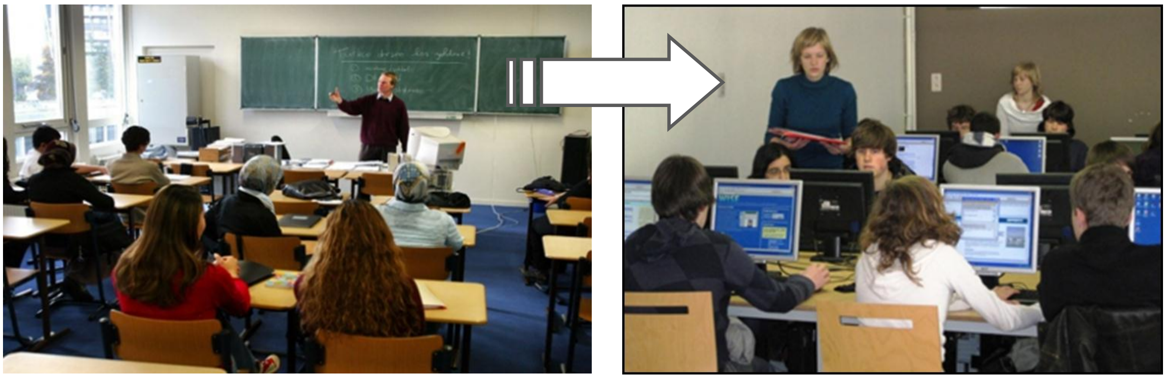

Figure 2: Changing teaching and learning context

The teaching and learning context changed from a situation in which the teachers stay in front of the classroom and students are listening to the teacher or working on identical exercise books and going through the exercises in a sequential manner (thus giving the teacher an easy overview of what students have done and what they will do next) to learning tasks which are more open-ended and have a less clear-cut sequential structure (thus making it much harder for the teacher to see what students have done and anticipate what they will do next) (Greiffenhagen, 2012).

It is noticeable that teachers have an ambivalent status in theories and studies of collaborative inquiry learning with computers (see, e.g., Koschmann 1996; Koschmann, Hall, & Miyake, 2002; Stahl, 2006). On the one hand, a lot of technological innovation in school classrooms has been driven by the aim of transforming teaching and learning from "teacher-led" whole class instruction to more "student-centered" practices which is based on the constructivist learning approach previously presented. On the other hand, it has always been recognized that teachers still play a crucial, albeit new, role during computer-supported collaborative inquiry learning activities. Conceptions of the learning process rooted in notions such as "scaffolding" and Vygotsky's "zone of proximal development" (1978) acknowledge that the teacher, although no longer the "sage on the stage", nevertheless has to act as a "guide on the side". However, Dillenbourg (2009) noticed that CSCL cannot have any major impact on schools by putting teachers "on the side". Slotta and Linn (2009, p. 119) suggest that web-based inquiry learning in science best works if the teacher acts as a "leader from within" who not only monitors students but actively engages them, helps them to synthesize their views, and maintains a dynamic process of exchange within the classroom.

Scaffolding computer-supported collaborative inquiry learning

The notion of scaffolding comes from the socio-constructivist model of learning (Vygotsky, 1978) and was originally introduced by Wood, Bruner, and Ross (1976), who believed that learning occurs in one-on-one interactions in which a more knowledgeable person guides a learner's emerging understanding. In accordance with Vygotsky's zone of proximal development, the scaffold should provide just enough information so that the learner may make progress on his or her own (Hogan & Pressley, 1997). However, the changing teaching and learning context does not allow that privilege, since a teacher cannot interact with every child or small group individually, and in accordance with this changing classroom context, also the notion of scaffolding has changed over time. Recently it has been claimed that during everyday classroom teaching, scaffolding needs to involve teacher, peers, and technology (Kim & Hannafin, 2011) and we need to better understand teachers' contributions to, and interplay among, students, peers, and technology in realistic classroom settings (McNeill & Krajcik, 2009; Puntambekar & Kolodner, 2005; Tabak, 2004). In line with the framework of Kim and Hannafin (2011), Reiser (2004) had previously argued that scaffolding needs to be perceived and examined as a system in which learners, tools, and teachers work together.

Different actors at different social planes

In line with this "system approach" (Reiser, 2004) and the framework of Kim and Hannafin (2011), the notion of orchestration can be put forth which refers to the process of flexibly and productively coordinating the help that the teacher needs to follow, on different levels and different planes, in CSCL environments (Dillenbourg, 2009; Fischer, Kollar, Mandl, & Haake, 2007). Four levels can be identified, that is, (1) the individual plane, (2) the group plane, (3) the class plane, and (4) the larger community plane. The latter level is out of the scope of this dissertation since this research focuses on implementation of CSCiL in authentic classrooms. The different social planes and interactions within and between the planes under investigation are depicted in Figure 3.

Figure 3: Different actors at the three social planes emerging when implementing CSCiL.

On the first plane the learner-system interactions can be identified: reading the task, answering the question, analyzing the graphs with the technology as the main source to support learning. The second plane focuses on interactions within small groups, both verbal interactions and task-level actions. The focus moves to the social interactions, shared regulation about solving the (information) problem and distributed cognition. Peers can be perceived as supporting sources and the technology moreover can help to structure the interaction and the quality of collaboration. Finally, the third plane is the school class, a complex “ecosystem” comprising several “species” and also including a physical environment, a content structure (the curriculum), and a rigid time structure. CSCL has neglected the existence of classes and their teachers for a long time, but now they get renewed attention (Greifenhagen, 2012; Rutten, van Joolingen, & van der Veen, 2012). Dillenbourg (2009) claimed to devote more energy to understand how design choices may facilitate productive teamwork in a class ecosystem and how this will influence the fulfillment of the objectives in science regarding different groups of students.

Main research questions

Three main research challenges for further research have become apparent from the examination of the conceptual framework outlined above and can be summarized in three broad research questions. These research questions are unraveled more deeply within the subsequent studies.

Research question 1 (RQ1): **What** can be achieved by means of computer-supported collaborative inquiry learning or what is the impact on students’ knowledge achievement, students’ inquiry skills and students’ motivation for science learning?

Research question 2 (RQ2): For **whom** is this learning approach suitable and beneficial and can we identify aptitude-by-treatment interactions based on student characteristics?

Research question 3 (RQ3): **How** should CSCiL be put into practice taking into account the everyday classroom context in which scaffolding needs to involve teacher, peers, and technology?

These research questions are considered particularly in the context of secondary science education (grades 9 and 10, i.e. 16 years old on average). This selection of secondary education rather then elementary education is based on the generally observed decline in motivation for science learning as soon as students start secondary education and the need for 21st century skills to prepare students for complex professional tasks in increasingly complex workplaces. Next to this, secondary schools are a challenging research context since teachers have less freedom in secondary education and the context is an inflexible structure compared to primary and higher education (Dillenbourg & Jermann, 2010; Greiffenhagen, 2012). Consequently, a lot of previous CSCL research has been conducted in higher education settings, whereas research in secondary education is still limited.

Research setting and methods

Design-based research approach

Overall, the research in this dissertation has been influenced by the design-based research (DBR) approach since the research studies were all carried out in the context of the implementation of computer-supported collaborative inquiry learning in authentic classrooms. The DBR approach is partly a reaction to the lack of theoretical base in designing and developing interventions to improve learning, the lack of evaluation studies in authentic settings, and the lack of theoretical implications of intervention research (The Design-Based Research Collective, 2003). Since this dissertation aimed to find out under which conditions CSCiL is most beneficial when implemented in the authentic classroom for a diversity of students, this research approach (Reeves, 2006) was appropriate to guide the overall research design. As depicted in Figure 4, a first phase was the problem-analysis which was performed based on an exploration of the educational landscape and international reports regarding science education in Flanders. A second phase consisted of the development of a possible solution to raise the motivation of students and at the same time, to increase achievement levels and obtain the 21st century skills that aim to prepare studetns for future workplaces. Although we recognize that next to teaching methods, also curricula and teacher education are in need of improvement at the level of school education in science (EACEA/Eurydice, 2011), the focus of this dissertation is limited to the micro level questioning the impact of computer-supported collaborative inquiry for science learning in secondary education. Several inquiry learning environments (ILE) have been identified that support learners, teachers, developers, and researchers. We decided to use the existing ILE WISE instead of starting anew since we could easily customize it so that it met the contextual needs. As recognized by Donnelly et al. (2014), enhancing existing platforms combines the efforts of many individuals and, thus, strengthens the field. In the context of this dissertation a WISE curriculum project about Global Climate Change has been developed based on the instructional pattern of the Knowledge Integration approach to learn about the underlying scientific phenomena including energy transfer from sun to earth, the greenhouse effect, and the role of the sun in photosynthesis. Additionally, the science of climate integrates the sciences of physics, chemistry, biology, and geography which provided an opportunity to apply an integrated science teaching approach that is increasingly stressed by educational policy and national standards. In the third phase, the project was implemented in authentic classrooms and effects on students' progress in knowledge, inquiry skills and motivation were tested. Next to this, students were asked to evaluate the teaching approach and to formulate suggestions for improvement. In the fourth phase, based on a first pilot, the WISE project, and more importantly the design choices regarding the support and guidance, could be refined to solve newly emerged problems. The overall dissertation consists of five iteration studies which will each be presented in a separate chapter. Throughout all phases of DBR, a collaborative partnership between researchers and practitioners took place (Anderson & Shattuck, 2012).

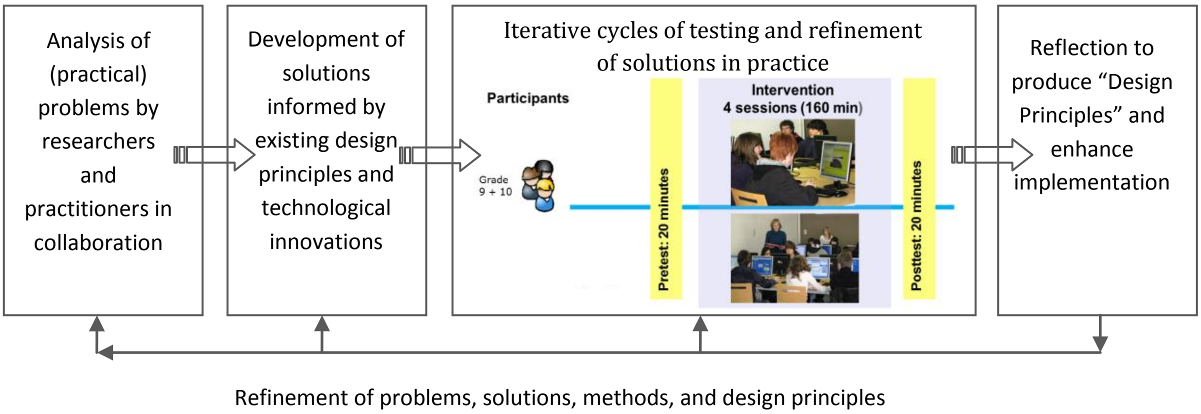

Figure 4. Reeve's Design-Based Research approach for educational technology research. Adapted from Reeves (2006)

Mixed methods approach

The DBR methodology is a well-used research approach in the Learning Sciences (Barab & Squire, 2004; Brown, 1992; The Design-Based Research Collective, 2003) and relies on multiple sources of evidence, both quantitative and qualitative, which are triangulated to make use of the strengths of both research paradigms (Johnson & Onwuegbuzie, 2004). Although the overall dissertation can be linked with the characteristics of DBR, each study can be regarded as a stand-alone quasi-experimental research study. Quasi-experimental studies investigate intervention effects in naturally constituted classes assigned to either an experimental or a control condition (Koul, 2009). The included studies largely represent quantitative research, whereby quantifiable data is collected that is statistically analyzed in an objective manner (Creswell, 2003). Quantitative research methods are useful for studying a large number of participants. However, qualitative research is also explored and employed, whereby data are collected which consist of participants' words and interactions. Qualitative research provides a more in-depth understanding of participants' interpretations and personal experiences situated and embedded in context. Here, data transformation is applied, whereby qualitative data are converted into numerical scores which can be analyzed statistically (Tashakkori & Teddlie, 2010).

Several authors (e.g. Creswell, 2008; Greene, 2008) suggest the power of integrating different approaches from a mixed methods perspective in answering research questions and in strengthening the inferences both in terms of processes of analysis and outcomes of analysis. Moreover, methodological pluralism enables errors in single approaches to be identified and rectified, and new modes of thinking to emerge where paradoxes between two individual data sources are found (Johnson et al., 2007 in Cohen, Manion, & Morrison, 2011, p.23). Data from different sources and from samples of different sizes, scope and type can be used within the same study (Teddlie & Tashakkori, 2009) to present for example multiple case studies in contrasting settings giving insight in "how" and "why" questions.

Overview of the dissertation

This dissertation entails seven chapters wherein, besides an introductory chapter (Chapter 1) and concluding chapter (Chapter 7), five studies are included (Chapters 2 to 6). Each of these five chapters documents on a different empirical study and is based on a published or submitted article in an international peer reviewed journal. Table 1 indicates which research questions are discussed in which chapter. Table 2 moreover provides an overview of the research objectives, research design and sample, data-collection and triangulation, and data-analysis techniques regarding the different studies.

Table 1

		Ch 2	Ch3	Ch4	Ch5	Ch6
RQ1 - WHAT	Knowledge integration	*	*	*		*
	Inquiry skills – Iinformation problem solving	*	*	*		
	Motivation/interest	*			*	
RQ 2 - WHO	Gender	*	*		*	*
	Achievement level	*	*		*	*
	Tracking	*			*	
RQ3 - HOW	Technology-enhanced support		*	*		*
	Peer support			*		
	Teacher-enhanced support		*			*

Chapter 1 is the general introduction of the present dissertation, wherein the conceptual framework and the resulting research questions are outlined. Furthermore, an overview of the design, methodology and studies included in the dissertation is provided.

Chapter 2, *Web-based collaborative inquiry to bridge gaps in secondary science education*, thoroughly analyses and describes the problem statement regarding the motivation for and performance in science education of Flemish students, and more particularly regarding gender differences, differences across achievement groups, and differences across academic tracks. This study outlines that schools are faced with the challenging task of providing adequate instruction to engage students – and more particularly the disadvantaged students – to learn science and improve their science inquiry skills. The integration of web-based collaborative inquiry is suggested as a possible answer; however, the differential effects of this teaching approach on disadvantaged students have barely been studied. To bridge this gap, this first study reports about the first implementation of the WISE project in 19 secondary classes, involving 370 students, and focuses specifically on gender, achievement level, and academic track. Multilevel analysis was applied to uncover the effects on knowledge acquisition, inquiry skills, and interest in science. Thus, this chapter generally builds on the first two research objectives, that is what can be achieved and for who is it most suitable and beneficial. This first chapter has been published in the *Journal of the Learning Sciences*.

Chapter 3, entitled *Scaffolding information problem solving during web-based collaborative inquiry learning,* comprises the study in which the WISE project was implemented for the second time. An important finding based on students' enactments during the first intervention was that students often struggled when searching the web during the inquiry activities. Based on this emerging issue, the focus on inquiry skills has been narrowed from general inquiry skills to science inquiry on the web or information problem solving. Moreover, next to questioning what can be achieved (RQ1) and for whom (RQ2), the second study also partly challenged the third research question about how to support students during science inquiry. A quasi-experimental study has been set up to investigate the impact of technology- and/or teacher-enhanced scaffolding on students' science learning and to explore the interaction effects with students' characteristics, which are gender and prior knowledge. The intervention study aimed to improve domain-specific knowledge and metacognitive awareness during online information problem solving as part of an online inquiry project. In total 347 students from 18 secondary school classes were involved and the classes were randomly distributed over four conditions (i.e. three experimental conditions: teacher-enhanced scaffolding, technology-enhanced scaffolding, and both forms of scaffolding and a control condition). This chapter has been published in *Computers & Education.*

Chapter 4, *Promoting shared regulation during joint information problem solving on the web,* zooms in on the collaborative processes taking place during web-based inquiry learning in authentic classroom settings. In this regard, this study focuses partly on the first research question taking into account the collaborative problem solving skills and partly on the third research question including how collaboration should be supported. Although collaboration is recommended since it has been found that student dyads are generally better in applying (information) problem solving (IPS) strategies, such as planning, monitoring and evaluating, and yield higher learning outcomes compared to students who work individually, successful collaboration and shared regulation is not guaranteed and may be hampered due to imbalances in participation in the group. The study described in Chapter 4 aimed to investigate the regulatory processes that come into play during collaborative IPS and to find out if these processes can be supported by providing students with a technology-enhanced collaboration script. For this study the WISE project was implemented for the third time and involved 202 students working in pairs, coming from 12 secondary school classes. Six classes were provided with a collaboration script embedded in the learning environment, while the other six classes acted as the control group. This study has been resubmitted to the journal *Metacognition & Learning* (after a first revision based on the editor's and reviewers' comments).

Chapter 5, *Unraveling the motivational effects and challenges of web-based collaborative inquiry learning across different groups of learners* focuses more deeply on one of the objectives in science education, that is motivation for science learning. This study unravels the contribution and challenges of CSCiL to foster students' motivation to learn science and its relation with student and class-level characteristics and thus is again a combination of research question one and two. An empirical mixed methods study in 13 secondary science classes was conducted, involving 220 students. Students' motivation was quantitatively studied based on the Self-Determination Theory and it was hypothesized that web-based collaborative inquiry can be considered as a need-supportive environment which in turn can foster autonomous motivation and decrease controlled motivation. In addition, qualitative analyses were conducted on students' experiences and future preferences regarding the WISE project to inform further refinement of the design of the implementation (cfr. RQ 3). This study has been resubmitted to the journal *Educational Technology Research and Development* (after a second (minor) revision based on the editor's and reviewers' comments).

Chapter 6, *The effects of teacher-led class interventions during technology-enhanced science inquiry on students' knowledge integration and basic need satisfaction,* relies on the findings of previous studies which revealed that students often do not feel competence satisfied during CSCiL and it is considered that teachers' class intervention can give solace. In this regard, this final study mainly focuses on the third research question about how CSCiL should be put into practice taking into account the everyday classroom context. Nevertheless, effects were investigated on students' domain knowledge and interaction effects were examined with students' characteristics, which builds on RQ1 and RQ2. This study investigated the effects of two differently designed classroom scripts that guided the teacher-led interventions during the course of the WISE Climate Change project. 168 students from 10 classes were randomly assigned to either the high-structured condition (more teacher interventions focusing on providing structure and feedback) or the low-structured condition (predominantly group work). Effects were measured on students' knowledge integration and students' need satisfaction. This study has been submitted to the journal *Computers & Education*.

Chapter 7 is the general discussion on the presented studies in the dissertation related to the main proposed research questions. Further, also strengths, limitations and future research aspirations are proposed. This chapter concludes with contributions and implications for research, practice, and policy.

Table 2

Outline of the Research Objectives, Research Design and Sample, Data-Collection and Triangulation, and Data-Analysis Technique per Chapter

Chapter	Research objectives	Research design and sample	Data collection and triangulation	Data-analysis techniques
1	General introduction (theoretical framework, research questions, research design and overview of the dissertation)			
2	Investigating the benefits of web-based collaborative inquiry learning for three disadvantaged groups: girls, low-achievers, and general-track students	Implementation in 19 classrooms Pre- and post-test design (n = 370)	Knowledge and Inquiry achievement test, Self report on the Interest in Science scale of the PISA assessment	Multilevel analysis (MLwiN)
3	Investigating the impact of multiple modes of scaffolding on students' domain-specific knowledge and students' metacognitive awareness during information problem solving Investigating if the way students are scaffolded interacts with students' personal characteristics, i.e. gender and students' level of prior knowledge	Implementation in 18 classrooms Two-by-two factorial quasi-experimental pre- and post-test design ($n_{exp.1}$= 72, $n_{exp.2}$= 97, $n_{exp.3}$= 101, n_{cont}= 63)	Knowledge achievement test, IPS task and self-report on the Metacognitive Awareness Inventory	One-way analyses of covariance (SPSS)
4	Investigating the regulatory processes that come into play when individual learners work collaboratively when solving information problems on the web and if these can be supported by providing students with a collaboration script	Implementation in 12 classrooms Two factorial quasi-experimental design ($n_{exp.}$= 99, n_{cont}= 108) Case-study design (n = 4 dyads)	Group performances, Self-report of the shared performance of the Big6 Strategies, audiotaped interactions of 20 dyads	Multilevel analysis (MLwiN) Qualitative case study analysis by means of interaction analysis
5	Investigating the effects on student motivation for science learning (autonomous and controlled motivation) Investigating to what extent the motivational effects are related with student and class-level characteristics. Investigating how students experience the WISE intervention and what students' future preferences are regarding WISE. And to what extent these are related with student and class-level characteristics	Implementation in 13 classrooms Pre- and post-test design (n = 220)	Science knowledge test, Motivation measured by means of Self report on the Academic Self-Regulation Questionnaire in pre- and posttest, and open ended evaluation question	Multilevel analysis (MLwiN) Pearson's Chi-square analysis (SPSS) Textual data analysis based on the grounded theory
6	Investigating if providing more structure and feedback during teacher-led class interventions leads to better knowledge integration and more basic need satisfaction Investigating if differentiated effects based on gender and achievement level can be identified	Implementation in 10 classrooms Two factorial quasi-experimental pre- and post-test design Two experimental ($n_{exp.}$= 81, n_{cont}= 87)	Student knowledge performance on pre- and post-test, group performances, basic need satisfaction measured by means of the Basic Psychological Needs Scale, logbooks, and observation data per classroom implementation	Multilevel analysis (MLwiN)
7	General conclusion and discussion (overview and discussion of the main results, limitations and suggestions for future research, implications of the dissertation)			

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2 Web-based collaborative inquiry to bridge gaps in secondary science education

This chapter is based on:

Raes, A., Schellens, T., & De Wever, B. (2014). Web-based Collaborative Inquiry to Bridge Gaps in Secondary Science. *Journal of the Learning Sciences, 23;* 316-347. doi: 10.1080/10508406.2013.836656

Chapter 2
Web-based collaborative inquiry to bridge gaps in secondary science education

Abstract

As secondary students' interest in science is decreasing, schools are faced with the challenging task of providing adequate instruction to engage students-and more particularly the disadvantaged students-to learn science and improve their science inquiry skills. In this respect, the integration of Web-based collaborative inquiry can be seen as a possible answer. However, the differential effects of Web-based inquiry on disadvantaged students have barely been studied. To bridge this gap, this study deals with the implementation of a Web-based inquiry project in 19 secondary classes and focuses specifically on gender, achievement level, and academic track. Multilevel analysis was applied to uncover the effects on knowledge acquisition, inquiry skills, and interest in science. The study provides quantitative evidence not only that a Web-based collaborative inquiry project is an effective approach for science learning, but that this approach can also offer advantages for students who are not typically successful in science or who are not enrolled in a science track. This approach can contribute to narrowing the gap between boys and girls in science and can give low-achieving students and general-track students an opportunity to develop confidence and skills for learning science, bringing them to a performance level that is closer to that of high-achieving students.

Introduction

The latest Eurobarometer on "Young People and Science" (European Commission, 2008) was conducted to determine young people's interest in science and technology, their views on various topics, and their plans for future involvement in the scientific domains. This large-scale survey of 25 000 people aged between 15 and 25 revealed that although young Europeans have a positive view of science and technology, only a minority of them consider a scientific study or career. In the area of Flanders specifically, the Program for International Student Assessment (PISA; Organization for Economic Co-operation and Development [OECD], 2007) revealed similar findings. Although Flemish students are ranked among the top performers in terms of scientific literacy, their motivation for science learning was below the OECD mean and only an absolute minority reported that they were considering pursuing scientific studies or a career in science (De Meyer, 2008).

In view of the increasing recognition of the importance and economic utility of scientific knowledge in an industrialized society, the general lack of interest in science and the consequent reduction in the numbers of young people choosing to study science has become a matter of considerable social concern and debate (Osborne, Simon, & Collins, 2003). Science education in schools seems to play an important role with regard to this problem. According to the Relevance of Science Education (ROSE) project - an international comparative project aiming to shed light on affective factors of importance regarding 15-year-old students' learning of science and technology - the lack of relevance of the Science & Technology curriculum is one of the greatest barriers to good learning as well as to interest in science content (Sjøberg & Schreiner, 2010). Nowadays, much of what goes on in contemporary science classrooms is not particularly attractive to students. While adolescents in the 21st century are immersed in a world in which they are connected to their peers, to technology, and to the web content in which they are interested, they enter science classrooms in which they are disconnected from their peers and from the tools they regularly employ for informal learning, and are often required to consume, complete, and replicate given knowledge (d'Apollonia, 2010). In addition, paradoxically, especially girls, low-achieving students in science and students from a general-track (i.e. without a focus on science in their curriculum) are often deprived from engaging in science instruction due to stereotypical beliefs and a self-fulfilling prophecy (explained further below). This results in a higher likelihood of considering science as boring, difficult, and irrelevant for their own lives (Eder, 1981; Flemish Government, 2006; Stark & Gray, 1999). To counter this problem, web-based collaborative inquiry learning can be put forth as a promising learning approach in an attempt to make science accessible and interesting to all academic tracks and to rectify the gaps in science education between high- and low-achieving students, and between girls and boys. First, it has been found that the disparities in science education are less distinct in small-group collaborative activities compared to whole-class activities (e.g., Kahle & Meece, 1994), as in small groups, the active participation of every student is expected and valued. Second, the use of ICT, and more particularly the World Wide Web during face-to-face science instruction, has benefits for science instruction due to its scope, flexibility, and accessibility to pursue questions of personal interest and compare ideas, analyze evidence for one's own ideas and distinguish among ideas (Linn & Eylon, 2011; Slotta & Linn, 2000; Wallace, Kupperman, Krajcik & Soloway, 2000). Web-based collaborative inquiry provides students with more autonomy and gives teachers the opportunity to adopt a role of facilitator of inquiry (Edelson, Gordin, & Pea, 1999; Krajcik et al, 1998). Although implementing web-based collaborative inquiry in educational practice is supported by national standards and educational policy (OECD, 2009; VLOR & VRWI, 2008), and despite the merits of this learning approach revealed by educational research (Bennett, Lubben, & Hogarth, 2007; Krajcik et al., 1998, Slotta & Linn, 2009; Mistler-Jackson & Songer, 2000), the implementation in science classroom settings is still limited (see also Cox et al., 2003; Mumtaz, 2000). In addition, large-scale quantitative research that investigates the effect of web-based collaborative science inquiry on disadvantaged students in science is not widely disseminated (Park, Khan, & Petrina, 2008). To fill these gaps in educational research, the present study aims to contribute to the field of the Learning Sciences by focusing on the differential effects of web-based collaborative inquiry learning on disadvantaged students. It is questioned whether there are differences in (learning) gains with regard to knowledge acquisition, inquiry skills, and interest in science which are related to gender, achievement level, and academic track. Web-based collaborative inquiry is investigated in authentic classroom settings comprising a substantial number of students (N = 370). Taking into account the complex situation that occurs when several factors interact, the quantitative evidence is presented by means of Hierarchical Linear Modeling in order to add to previous research in this area, which often encompassed only a small number of students and focused more on qualitative analyses (e.g. Mistler-Jackson & Songer, 2000).

Theoretical and Empirical Framework

Differences in science education

Gender gap

Although we are experiencing a steady growth in the number of female students enrolling in university and higher education (Machina & Gokhale, 2010; Meulders, Plasman, & Rigo, 2009), females are still under-represented in faculties of sciences (Taasoobshirazi & Carr, 2008). Moreover, according to the Flemish Board for Scientific Policy, the participation of females in these fields of study (especially in exact and applied sciences) is still decreasing (VLOR & VRWI, 2008). The fact that girls and boys often experience qualitatively different educational situations, due to the stereotypical belief that science is a male domain, is often documented as an important factor (e.g. Greenfield, 1996). Several studies (e.g. Jones & Wheatley, 1990; Kahle, Parker, Rennie & Riley, 1993; Sadker & Sadker, 1994) have indicated that in science classrooms, boys often receive more attention from teachers than girls do, as they are called upon more frequently to answer questions, given more freedom to call out answers, and receive more detailed process feedback on their work efforts.

Differences across achievement groups

With regard to low-achieving students, teachers often hold the prevalent conception that higher-order learning goals in science education - such as knowledge building (Chan & Lee, 2007) and knowledge integration (Slotta & Linn, 2009) activities based on the assumption that knowledge needs to be constructed by the learners - are only suitable for certain students, particularly those with higher cognitive abilities. This belief gives rise to a self-fulfilling prophecy, as teachers tend to avoid the use of higher-order thinking interactions with low-achieving students, meaning that they are “stuck” with learning activities that emphasize memorization and methods of drill and practice (Zohar, Degani, & Vaaknin, 2001; Zohar & Dori, 2003).

Differences across academic tracks

A self-fulfilling prophecy can also be discerned regarding different science class types or tracks (Eder, 1981). In many educational systems, including the Flemish system, students are separated into different academic tracks, which consist of a package of courses focusing on languages, economics, and/or science, respectively. Dividing students into different academic tracks occurs primarily on the basis of their proficiency as determined by previous course grades, yet tracking also occurs based on student and parent choice (Pickens & Eick, 2009). Studies have shown that differences in teacher expectations regarding student science learning, caused by tracking, also result in a differing quality of teaching science (Nieswandt & Shanahan, 2008; Pickens & Eick, 2009). Students in science tracks receive instruction emphasizing scientific reasoning and inquiry-based instruction (Haury & Milbourne, 1999), whereas general-track students receive less challenging instruction, and are subsequently less motivated to learn science (Oakes, 2005).

Web-based collaborative inquiry learning as a possible solution

As science education faces a challenging task in providing adequate instruction to meet the needs of a diversity of students, it can be questioned whether learning science by means of web-based collaborative inquiry learning could be beneficial for all students. To contribute to previous research in the field, this study focuses particularly on the benefits of web-based collaborative inquiry learning for the three aforementioned disadvantaged groups (i.e. girls, low-achievers, and general-track students) by means of a (relatively) large-scale intervention study in authentic classrooms.

The overall benefits

Inquiry-oriented science instruction has been characterized in a variety of ways over the years and has been promoted from various perspectives (DeBoer, 2000; Krajcik et al., 1998; Rakow, 1985; White & Frederiksen, 1998). In general, it can be assumed that inquiry-based learning is a student-centered learning approach in which students are stimulated to work together and get involved in a social, active, engaged, and constructive learning process, as opposed to more traditional approaches, which tend to emphasize the memorizing of factual information. In web-based collaborative inquiry more specifically, the Web is used as a source for knowledge exploration and inquiry in science (Chang, Sung, & Lee, 2003). Moreover, Wallace et al. (2000) state that the Web can be seen as an information resource, which opens the boundaries of the classroom and creates the possibility for students to pursue questions of personal interest.

When we speak of benefits, we need to refer to the expected learning outcomes in science education. First, science education aims to improve students' scientific knowledge; second, science education aims to improve students' inquiry skills; and third, science education aims to get students interested in science so that they may consider scientific studies or a career in science. Based on evidence from the literature, we can assume that web-based collaborative inquiry can help to achieve these three interrelated objectives in science education.

With regard to the first learning objective, it should be stated that in the context of web-based inquiry learning, the notion of knowledge acquisition is not the traditional one of recalling isolated bits of information (which Linn & Eylon (2011) refer to as the absorption approach), but rather the knowledge integration approach. Knowledge integration has been conceptualized based on research from the Technology Enhanced Learning in Science (TELS) community, which was started in the 1980s (see e.g. Slotta & Linn, 2009). Knowledge integration can be defined as the process of incorporating new information into a body of existing knowledge by guiding students to engage in inquiry (Linn & Eylon, 2011). This approach builds on extensive evidence (see e.g. Howe, 1998, Linn & Hsi, 2000) that every student brings a repertoire of rich, confusing, and intriguing ideas to the science class and that students need to build on these ideas. Students need to link their ideas to new ideas and they need evidence to sort through the alternative ideas they hold. With regard to knowledge integration, previous research has compared traditional instruction with web-based inquiry instruction with regard to students' ability to make connections between scientific topics. The findings indicated that students in the web-based inquiry cohort performed better than students in the traditional cohort (Linn, Lee, Tinker, Husic, & Chiu, 2006; Lee, Linn, Varma, & Liu, 2010). These results show that technology-enhanced inquiry projects in key science topics can be successful and can enable students to outperform peers experiencing traditional instruction in terms of integrated, coherent understanding of scientific knowledge as well as the robustness of their understanding (Linn & Eylon, 2011).

Second, web-based inquiry aims at the development of inquiry skills. According to the knowledge integration approach, inquiry can be defined as the intentional process of diagnosing problems, generating hypotheses, critiquing experiments, planning investigations, searching for information, constructing explanations, debating with peers, and forming coherent arguments (Linn & Eylon, 2011). As the World Wide Web is used as a source within inquiry learning, this opens the boundaries of the classroom because of the availability and searchability of a large amount of information. The World Wide Web gives more opportunities to pursue questions of personal interest and compare ideas, analyze evidence for one's own ideas and distinguish among ideas (Linn & Eylon, 2011; Slotta & Linn, 2000; Wallace et al., 2000). Engaging students in this type of inquiry learning has been found to improve not only the integrated understanding about science topics but also students' ideas about scientific methods and the image of experimentation that students acquire. Linn and Eylon (2011) state that when students learn experimentation based on the knowledge integration approach, they are prepared to solve new problems, develop an understanding of advances in technology, expand their ability to critique persuasive messages, and become lifelong learners. Activities that emphasize debate or critique more specifically can help students to critically deal with and judge scientific information from different sources including the web (Linn, Davis, & Bell, 2004).

Regarding the third objective, that is, interest in science, it is found that connecting science with everyday life and engaging students in collaborative activities with personal and future relevance is crucial, because such connections can trigger changes in students' motivational structure toward more intrinsic orientations (Bransford, Brown, & Cocking, 2000; Nieswandt & Shanahan, 2008). The knowledge integration approach, fostering the web-based inquiry science environment used in this study (and further explained in the method section), is also designed to motivate learners to revisit their image of science through the principle of making science accessible in order to increase its relevance for students. It has been found that in addition to improving understanding of science concepts, integrated projects including the aforementioned inquiry activities increase interest in science (Sadler, Chambers, & Zeidler, 2004). In addition, information and computer technologies can contribute to student motivation by enhancing challenge, variety, and choice through the provision of multiple levels of tasks and worldwide access to numerous sources of information (Blumenfeld et al., 1991; Chang et al. 2003). In this respect, numerous studies suggest that web-based inquiry-oriented science instruction can be effective in producing positive student attitudes toward science and toward science instruction (Lee & Erdogan, 2007; Slotta & Linn, 2009).

Beneficial for all students?

Although previous research has already revealed the general benefits of web-based collaborative inquiry, the study of the effects of web-based collaborative inquiry on disadvantaged students in science is sparse (Park et al., 2008). However, it is not yet clear whether it is beneficial for all students.

With regard to gender, it has been found that while some research reported gender issues regarding technology-enhanced learning, concerning women's level of anxiety and their lack of confidence (Durndell, Glissov, & Siann, 1995; Okebukola & Benwoda, 1993) in contrast to male dominance (Prinsen, Volman, & Terwel, 2007), other studies revealed positive attitudes of girls toward learning with computers and the World Wide Web. Girls especially appreciated the social function of the computer, that is the ability to communicate with others and to share ideas, stories, news, and advice using email or real-time communication programs (Leong & Hawamdeh, 1999). An in-depth case study by Mayer-Smith, Pedretti, and Woodrow (2000) found that woman do enjoy and are successful in learning science in a technology-enriched environment without the manifestation of the levels of anxiety or the lack of confidence often reported by other researchers. Moreover, a meta-analysis of 61 studies on the effects of context-based science education on students aged 11-18 found that gender differences in attitude were "narrow" as a result of context-based interventions (Bennett et al., 2007). Context-based courses appear to have a positive impact on overall performance, and on girls' performance relative to that of boys (Murphy & Whitelegg, 2006). Based on these findings, we can assume that web-based collaborative inquiry will not hamper girls' science learning due to the use of computers and the internet. Moreover, we propose that girls can even benefit from this kind of science learning due to the opportunity to share and discuss ideas about science topics connected with everyday life. In previous research with web-based inquiry projects more specifically, no differences were found between boys and girls engaging in these projects (Linn & Eylon, 2011, p. 297), although research focusing on this gender issue is limited.

As discussed above, it has been found that general-track students and low-achieving students in science are often deprived from instruction emphasizing scientific reasoning and inquiry-based instruction due to teachers' self-fulfilling prophecy. In other words, teachers often hold the prevalent conception that higher-order learning goals such as reflective science inquiry on the web are only suitable for certain students, especially those with higher cognitive abilities, and thus do not give other students the chance to actually benefit (Nieswandt & Shanahan, 2008; Oakes, 2005; Pickens & Eick, 2009). In contrast, it has been found that science curricula emphasizing higher-order thinking skills such as reflective inquiry can be effective for both high- and low-achieving students in science (Chan & Lee, 2007; So, Seah, & Toh-Heng, 2010; Zohar & Dori, 2003). Moreover, in one of their studies, Zohar and Dori (2003) found that the net achievement gain in inquiry science learning was significantly higher for low-achievers. Consequently, it may be assumed that the ambitious instructional context represented by web-based inquiry science teaching has unique opportunities and might even benefit educationally disadvantaged students when appropriate scaffolding is provided (Palincsar, Magnusson, Collins, & Cutter, 2001; White & Frederiksen, 1998). Nevertheless, studies examining the effects of web-based inquiry on students with different achievement levels are limited. Slotta and Linn (2009), for example, only mention one study in which students who scored below and above the median on the pre-test were compared, and found that they achieved comparable learning gains after a web-based collaborative inquiry project.

There is also little research concerning students from different academic tracks. Niu and van Aalst (2005) examined the extent to which a knowledge-building approach, which in a sense is comparable to the knowledge integration approach due to a shared emphasis on collaboration and computer-supported inquiry, was beneficial across courses differing in academic level, namely regular and honors classes in Canada. In their study of high-school students using Knowledge Forum, an electronic group workspace designed to support the process of knowledge building, it was found that while the students in the honors class did better than those in the regular class, the effect was influenced more by within-class differences than by between-class differences. Moreover, in some of the qualitative measures, the regular students outperformed the honors students. However, the knowledge-building approach was studied during students' participation in asynchronous online discourse. Moreover, it is difficult to deduce general conclusions from this study as the educational system of regular and honors classes in Canada is very different from an educational system with general- versus science-tracks. Research in such an educational context is needed in order to gain insights into the benefits for differentially tracked students.

Research questions

Although collaborative inquiry has been widely researched in the Learning Sciences, this study addresses three aforementioned gaps in the existing literature: 1) The main focus of the study is on the benefits of web-based collaborative inquiry learning for three disadvantaged groups: girls, low-achievers, and general-track students; 2) the research project implements web-based collaborative inquiry in a variety of authentic science classrooms; and 3) effects are measured on a (relatively) large scale, including 370 students from 19 secondary school classes.

Differential effects are investigated regarding students' gains in knowledge acquisition, their development of inquiry skills and their interest in science. Based on previous research, it is hypothesized that web-based collaborative inquiry can also benefit a more diverse population of students. First, it is hypothesized that web-based inquiry science projects can benefit girls due to the opportunity to share and discuss ideas about science topics connected with everyday life. Second, it is hypothesized that it can also benefit low-achieving students in science, as the knowledge integration approach respects the ideas of all learners and gives all students the chance to express their thoughts working at their own pace. Third, it is hypothesized that this learning approach is suitable and beneficial for science as well as general-track students as it can counter the prominent self-fulfilling prophecy.

Method

Learning Environment

The opportunities of web-based collaborative inquiry are reflected in several theory-driven learning environments which have been researched worldwide in the Learning Sciences and more specifically in the context of Computer-Supported Collaborative Learning (CSCL) research. The Web-Based Inquiry Science Environment (henceforth referred to as WISE), from the University of California at Berkeley, was developed along the lines of the knowledge integration approach. This is the learning environment used in the present study to implement and investigate web-based collaborative science inquiry in educational practice. WISE is a powerful online platform for designing, developing, and implementing science inquiry activities. As depicted in Figure 1, WISE provides a teacher's portal including possibilities for classroom management, student assessment and creating or editing curriculum projects. Besides this, a student interface is available, with the inquiry map on the left side, which structures the activities in several steps, and the provided activity on the right side. The learning environment supports the implementation of inquiry steps of various kinds, for instance exploring a simulation, brainstorming, constructing an argument, reflection and self-assessments. During a WISE project, students work in pairs and all of their teamwork is stored in a database which is accessible to teachers and researchers for purposes of assessment.

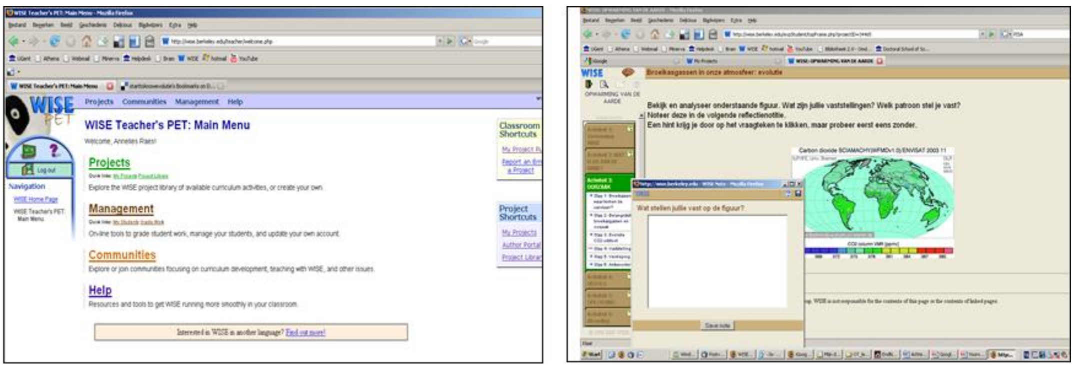

Figure 1. The Web-based Inquiry Science Environment. On the left side a screenshot of the Teacher's Portal. On the right side a screenshot of the Students' Portal.

The WISE authoring environment was used to create a new curriculum project which was closely tied to the regular curriculum and was integrated with teaching and learning practices in Flemish educational practice. The new WISE curriculum project was designed in partnership with science teachers and technology specialists based on the co-design approach of Peters and Slotta (2009). Global warming and climate change was chosen as the topic under investigation because this topic is current and familiar to students. Global warming is an issue that students have heard about, but due to the uncertainty and controversy in the scientific community regarding the scientific issues associated with climate change, it can be considered as a complex topic. Moreover, students often struggle with the underlying scientific phenomena, including energy transfer from sun to earth, the greenhouse effect, and the role of sun in photosynthesis, which are included in the secondary science education content standards. In addition, the science of climate is an interesting area for study because it integrates the sciences of physics, chemistry, biology, and geography. In this way, it provides an opportunity to apply a system approach to science learning that is increasingly stressed by educational policy and national standards. The aim of the curriculum was a joint emphasis on learning why the environment matters and on building an understanding of the scientific phenomena involved.

Based on the knowledge integration approach previously described, Slotta & Linn (2009) built a design framework for science curriculum projects as shown in Table 1. Four categories of design goals are reflected in the principles included in the framework: "Make science accessible - Make thinking visible - Help students learn from others - Promote autonomy". Moreover, the design of the activities is based on the instructional pattern "Elicit ideas – Add new ideas – Distinguish among ideas – Reflect on and integrate ideas". Table 1 contains examples of corresponding project activities in our global climate change project. Each activity starts with eliciting the ideas that students already hold. Subsequently, students get the opportunity to add new ideas and distinguish among ideas by searching and critiquing web-based evidence, exploring provided simulations or interactive graphs, and discussing with peers. Finally, students are asked to reflect on these ideas in order to integrate them into their repertoire of ideas.

Table 1

The table contains examples of project activities in the global climate change project based on the Knowledge Integration (KI) approach (Slotta & Linn, 2009)

KI Principles	KI Instructional Pattern			
	Elicit ideas	Add new ideas	Distinguish among ideas	Reflect and integrate ideas
Making science accessible to all student	Generate hypotheses about student's personal impact on climate change	Students calculate their own ecological footprint on the WWF website	Students compare their Ecological Footprint to others'	Reflecting about how to reduce the personal impact
Making thinking visible	Generate hypotheses about differential impact among wealthy and poor countries	Analyzing CO2-emissions trends across different countries in the interactive graph Gapminder World	Evaluate evidence about differential impact	Connect results of the interactive graph to personal hypotheses

Helping students learn from each other	Brainstorm to be prepared for online classroom debate between believers and non-believers	Search for evidence for human activities or natural processes which cause climate change	Comparing viewpoints during classroom debate	Create group consensus about the main cause for global climate change
Promoting Autonomy for lifelong science learning	Identify research question(s) that address specific gaps in their own science knowledge	Generate, read, listen, or observe ideas/ evidence	Critique and validate Internet evidence on the strengths and weaknesses	Connect evidence from the web with personal understanding

Participants

To study the differential effects of web-based collaborative inquiry on different types of students, the global climate change curriculum project was implemented in authentic classrooms as illustrated in Figure 2. A request for participation in this project was distributed via email to the principals of the secondary schools in two provinces in Flanders. In the email, the principals were asked to redirect this request to their science teachers. In the further phases, we communicated directly with the science teachers who had volunteered to participate with their class in this research project. A group of 17 science teachers were involved in the research project, each with one or two of their classes, and they agreed to devote four 50-minute lessons to implementing and evaluating the web-based inquiry project. These participating classes originated from 15 Flemish secondary schools and consisted of a mix of differentially tracked course programs, that is 22% following a general-track and 78% following a science-track. In total, 370 students from 19 secondary school classes (grades 9 and 10) participated in this study. The average age of the students was 16 years; 54% were girls and 46% were boys.

White and Frederiksen (1998) determined that it is not sufficient to simply provide teachers with teacher's guides that attempt to outline goals, suggest activities, and describe how lessons might proceed. Teachers additionally need to develop a conceptual framework for characterizing good inquiry teaching. As the classroom teachers did not have the time to go through a training period beforehand and the interventions had to be carried out according to a set of instructional principles, it was decided to involve 46 Master's students in Educational Sciences in this study to conduct and support the implementation of the WISE project. Thus, the Master's students served as the actual teachers during the project, while the regular classroom teachers predominantly observed the learning processes. For these Master's students, this assignment was a formal part of the 7-credit course in Educational Technology at Ghent University. All Master's students underwent thorough preparatory training. They had expertise in the theoretical backgrounds of CSCL and were familiar with the inquiry-based learning environment. The 46 Master's students were divided across the 19 classes participating in this study, resulting in eight classes supported by three Master's students each, and eleven classes supported by two Master's students each.

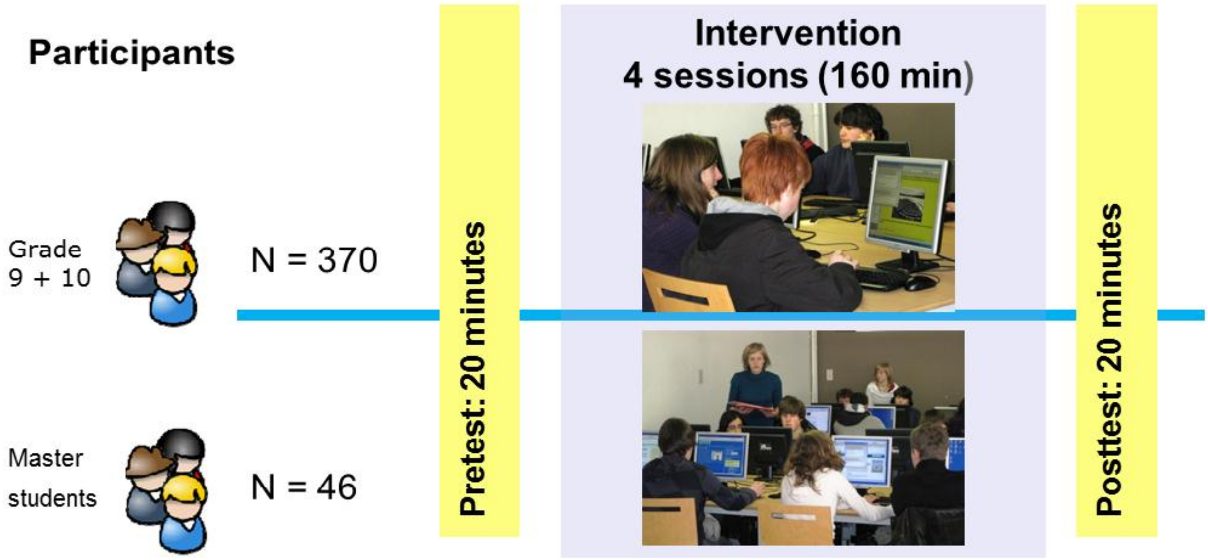

Figure 2. The pre- and post-test design to study the implementation of the web-based inquiry science project in authentic classrooms.

Design and procedure

By means of a quasi-experimental pre- and post-test design, this study focused on differential effects of web-based science inquiry for different existing groups of students (boys vs. girls, low- vs. high-achievers, science-track vs. general-track students).

Before students started the Global Climate Change project, they completed an individual pre-test. Afterwards, they were free to choose a partner and to complete the WISE project with this partner. This free choice led to dyad compositions of various types with regard to gender (only girls, only boys, and mixed group) and with regard to achievement (only high-achievers; only low-achievers; and mixed achievement levels). Students worked in the same dyads during the whole project. The Master's students had been trained to take over the role of the teacher during the lessons, and act as a "leader from within" instead of a "guide on the side". A "leader from within" not only monitors students but actively engages the students, helps them to synthesize their views, and maintains a dynamic process of exchange within the classroom (Slotta & Linn, 2009). After each lesson, Master's students provided electronic feedback (both positive and critical) through the feedback tool of WISE. After completing the curriculum project, all students completed an individual post-test. The students whose pre- or post-test was missing due to absence from this particular lesson were excluded from the dataset. Therefore, 356 students remained for data analysis.

Dependent variables and measures

The dependent variables in this study are students' domain-specific knowledge, inquiry skills, and interest in science, all measured on an individual basis in pre- and post-test. The following instruments were employed: 1) a pre- and post-achievement test to investigate knowledge acquisition and the acquisition of inquiry skills, and 2) a pre- and post-questionnaire to gauge students' interest in science. As the curriculum project was designed based on the knowledge integration framework, which aims at an integrated and coherent understanding of science, the outcome measures evaluated the extent to which students are able to link and connect ideas using evidence instead of merely recalling isolated ideas. The pre- and post-achievement test to investigate the learning effect on knowledge acquisition consisted of thirteen assessment items: eight items were open-ended knowledge questions scored on a rubric from 0-3, while the remaining five items asked students to first answer a multiple-choice question and then to explain the scientific idea behind their answer (this explanation was scored on a rubric from 0-4). Appendix A provides examples of the assessment items. The items were scored using an adapted version of the knowledge integration rubric created by the Technology Enhanced Learning in Science Community (TELS, 2010), which rewards both accurate and connected ideas. The rubrics displayed in Appendix B and C contain a number of proficiency levels, with higher proficiency levels reflecting a higher complexity of skills that students have to master in order to tackle the scientific problems. The scores of the eight knowledge and five explanation items were summed up to form a score for knowledge acquisition (min. 0 - max. 44).

The second part of the achievement test aims to measure students' science inquiry skills. In a pre- and post-test, students were presented with a short scientific article (around 300 words). To ensure that any differential effects were not the result of varying task difficulty, two different articles selected from a scientific magazine (i.e. "Smoking explains only half of the cases of lung cancer among unskilled people" and "Frequent marijuana use increases testicular cancer") were used and counterbalanced across two groups. Students were asked to extract the underlying research question from the text, to recite two hypotheses stated in the research, and to describe how they would investigate one of the stated hypotheses. The articles did not provide information about the research method. Students' open answers were coded based on the following rubric: 1) Is the underlying research question clearly formulated? (score 0-2); 2) Are the two hypotheses correctly and clearly recited? (score 0-2); 3) Are the participants of the proposed research clearly formulated? (score 0-2); 4) Is the treatment that needs to be tested clearly formulated? (score 0-2); and 5) Is the dependent variable according to which the effect is investigated clearly described? (score 0-2). The marks were added up to form a score for students' inquiry skills (min. 0 – max. 10).

The answers to the knowledge and inquiry achievement tests were coded by two independent raters who were both trained to use the rubric. The first rater coded the answers of all students and these were used for data analyses. To check the inter-rater reliability, a second rater independently coded the answers of 30 % of the students. Regarding all items, Krippendorff's alpha ranged from 0.65 to 1, which indicates good to excellent inter-rater agreement (Hayes & Krippendorff, 2007).

In order to assess students' interest in science, one scale from the science assessment of the PISA study (OECD, 2007) was used. The original PISA questionnaire measured students' attitudes toward science in different areas including support for scientific inquiry (e.g. 'Advances in science and technology usually improve people's living'), interest in science (e.g. *"I'm interested in learning new thing about science"*), and responsibility for sustainable development as an international concern (e.g. *"I'm aware of the consequences of clearing forests for other land use"*). In this study, we focus on students' interest in science and thus only used the interest in science scale of the PISA assessment. This scale includes nine items requiring students to express their level of agreement on a five-point Likert scale with statements expressing interest in science. The Cronbach's alphas of the interest in science scale were 0.91 for pre-test and 0.92 for post-test, which are acceptable reliability coefficients (Nunnally, 1978).

Multilevel analysis

Given the design, the present study focused on individual pre- and post-test comparisons across existing groups. Nevertheless, as the students worked together in small groups and these groups originated from existing classes, the problem under investigation has a clear hierarchical structure. In this respect, the analysis of test data at an individual level raises a methodological issue which is frequently discussed in research on group learning and collaborative problem-solving (e.g. Cress, 2008; De Wever, Van Keer, Schellens, & Valcke, 2007). Hierarchical Linear Modeling (HLM) is suggested as an alternative and adequate statistical approach in CSCL research as it enables the testing of main effects and interaction effects of predictor variables on different levels.

Owing to the pre- and post-test design used in this study, our data analysis encompasses repeated measures on individuals over time. The test time was then added as a dummy variable (0 = pre-test or T0, 1 = post-test or T1). Consequently, a four-level structure arose: Both test times (level 1) are clustered within students (level 2), which are nested within dyads (level 3), which in turn are nested within classrooms (level 4).

The following independent variables were taken into account: gender (boys vs. girls) and achievement level (low vs. high based on the mean achievement pre-test score of their class) at the student level; academic track (science-track vs. general-track) at the class level; and finally, dyad composition based on gender with three categories (only girls, only boys, and mixed group), and dyad composition based on achievement with three categories (only high-achievers; only low-achievers; and mixed achievement levels) at the group level.

The software MLwiN 2.23 for multilevel analysis was used to analyze the hierarchical data (Hox, 1994). A three-step procedure was followed to analyze the effects of the presented independent variables on the three dependent variables, that is knowledge acquisition, inquiry skills, and interest in science. The first step consisted of the estimation of a four-level conceptual null model, which serves as a baseline model. This unconditional null model without any predictor variables provides both the overall pre-test score and the overall learning gain for all students across all groups and classes. Moreover, by means of intraclass correlation, the model answers the question of whether the outcome measures vary among students, across dyads and across classes. The second step concerned the input of the three main independent variables (gender, achievement level and academic track) in the fixed part of the model and allows cross-level interactions to be detected between student and class characteristics. This resulted in model 1, which provides insight into the differential effects for different groups of students with different student and class characteristics. Finally, in the third step, the aggregated characteristics based on gender and achievement level, that is the group composition, were added to the model.

Results

Knowledge acquisition

The models that were built following the stepwise procedure described above are presented in Table 2. As we used a repeated-measures approach, our conceptual unconditional null model (model 0) predicts the overall knowledge score on the pre-test across all students, dyads and classes (= the intercept, i.e. 19.52 out of 44) as well as students' overall significant learning gain (slope β_1, i.e. 11.19) with regard to knowledge acquisition. Consequently, the overall score on the post-test was the sum of the intercept and the slope β_1 resulting in 30.71 out of 44 (i.e. 19.52+ 11.19). This model also gives rise to two residuals as shown in the random part of the model, one for pre-test, and one for learning gain. The null model divides the variance of the pre-test scores as well as the variance of the learning gain into between-classes, between-dyads and between-students components. The total variance of the pre-test scores is 48.92, which is the sum of the between-classes (level 4) variance (= 17.62), the within-class, between-dyads (level 3) variance (= 11.97); and the within-dyad, between-students (level 2) variance (= 19.33). After calculation of the intra-class correlation, which reveals the correlation of the observations (cases) within each cluster on the different levels, we can state that 36.03 % of total pre-test variance lies at the class level, the proportion of variance due to differences between dyads is 24.46%, and finally, 39.51% of total variance lies at the student level. As depicted in Table 2, these variances in pre-test scores on the three levels are significantly different from zero at the p <.001 level. With respect to the variance in learning gain, we also find significant variances at the three levels. The total variance consists of 34.43% between-class variance, 20.42% between-dyad variance, and 45.15% between-student variance.

Table 2

Multilevel parameter estimates for the four-level analyses of students' knowledge acquisition

Parameter	Model 0	Model 1
Fixed part		
Intercept	19.52 (1.01)	25.46 (0.94)
Learning gain	11.19*** (0.99)	7.07*** (1.15)
Girl		-.0.86 (0.60)
Low		-8.65*** (0.61)
General track		-7.73*** (2.09)
Girl*Low		0.89 (0.84)
Girl*General track		1.43 (1.27)
Low*General track		1.49 (1.38)
Girl*Low*General track		-4.31* (1.79)
Girl*Learning gain		1.22 (0.82)
Low*Learning gain		5.65*** (0.83)
General track*Learning gain		5.33* (2.53)
Girl*Low*Learning gain		0.73 (1.15)
Girl*General track*Learning gain		-5.3** (1.73)
Low*General track*Learning gain		-2.60 (1.86)
Girl*Low*General track*Learning gain		5.78* (2.43)
Random part		
Level 4 - Class		
Intercept/intercept (σ^2_{f0})	17.62*** (6.36)	10.93** (3.69)
Learning gain/learning gain (σ^2_{f1})	17.10*** (6.18)	15.13**(5.24)
Learning gain/intercept (σ^2_{f10})	-8.15 (4.97)	-5.58 (3.41)
Level 3 - Group		
Intercept/intercept (σ^2_{v0})	11.97*** (2.68)	1.53 (0.91)
Learning gain/learning gain (σ^2_{v1})	10.14*** (2.73)	3.96* (1.71)
Learning gain/intercept (σ^2_{v10})	-9.67*** (2.38)	-1.45 (1.01)
Level 2 - Student		
Intercept/intercept (σ^2_{u0})	19.33*** (2.10)	9.78*** (1.06)
Learning gain/learning gain (σ^2_{u1})	22.42*** (2.43)	17.02*** (1.84)
Learning gain/intercept (σ^2_{u10})	-13.55*** (1.91)	-6.96*** (1.12)
Level 1 – Test time		
Intercept/intercept (σ^2_{e0})	0.00 (0.00)	0.00 (0.00)
Model fit		
-2*log likelihood (Deviance)	4282.38	3939.89
χ^2		342.49
df		14
p		<.001
Reference model		Model 0

Note. Standard errors are in parentheses. * *p*<.05 ** *p*<.01 *** *p*<.001

Subsequently, based on the theoretical framework, gender, achievement level and academic track were added to the model as potential explanatory variables. All predictors were included in the model as fixed main and interaction effects. Model 1 displayed in Table 2 shows the results of this factorial model. The reference group to which the other groups of students are compared is, in this case, a boy who is a high-achiever and is following a science-track. Adding these variables to the null model resulted in a better model fit (χ^2 = 342.49, *df* = 14, *p* < .001). Based on this model, Figure 3 depicts the adjusted predicted means for the different groups of students in order to visually represent the results of this model. A low-achieving girl from a general-track, for example, scored 7.7 on the pre-test (i.e. based on table 2: 25.46 - 0.86 - 8.65 - 7.73 + 0.89 + 1.43 + 1.49 - 4.31) and achieved a learning gain of 17.9 (i.e. 7.07 + 1.22 + 5.65 + 5.33 + 0.73 - 5.3 - 2.6 + 5.78), which resulted in a post-test score of 25.6.

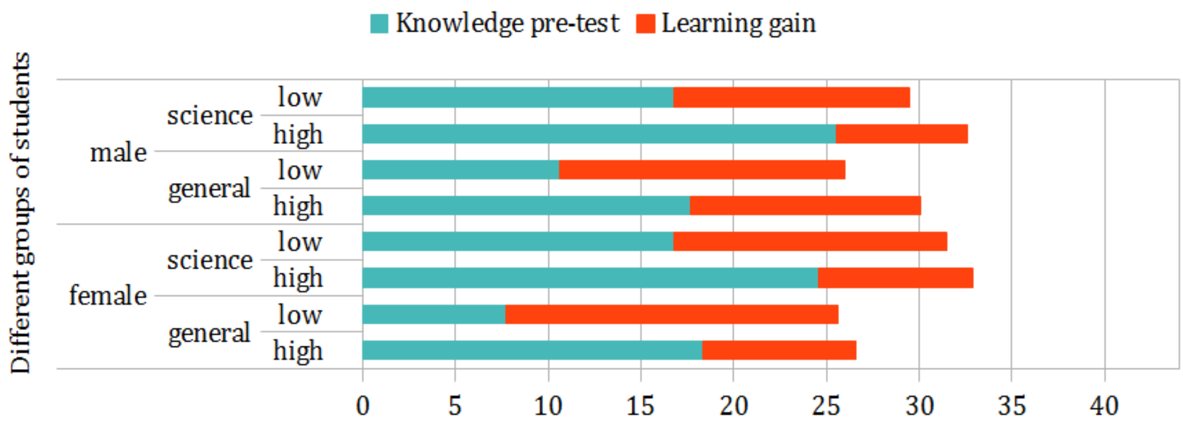

Figure 3. Graphical representation of the adjusted predicted means of knowledge scores and learning gains for the different groups of students. The full bar represents the post-test score (min 0 – max 44).

The results presented in model 1 indicate that no significant main effects are found regarding gender with respect to both pre-test scores and learning gain in knowledge. This means that overall, boys and girls do not significantly differ with respect to knowledge pre-test scores or learning gain scores. Achievement level and academic track, however, are significant predictors of pre-test scores and of learning gain scores. On the one hand, low-achieving students and students following a general-track scored significantly lower on the pre-test compared to high-achieving students and students following a science-track. On the other hand, these students achieved significantly higher learning gains compared to high-achievers and science-track students. Although overall, high-achievers started the project with higher prior knowledge, they did not reach the highest possible scores on the knowledge test, meaning that these results are unlikely to be due to a ceiling effect restricting the gains for the high-achieving students.

Nevertheless, these main effects only tell part of the story. Although no significant gender differences were revealed regarding the overall knowledge performance, some interaction effects were found. Based on the significant three-way interaction of girl*low-achiever*general-track, we can state that while female low-achievers from the general-track started the project with significantly lower pre-test scores (= 7.7), they achieved the highest learning gains (= 17.9), bringing their post-test score to a level that is closer to that of other groups. As can been seen in

Figure 3, this closes the gap between female low-achievers from the general-track and similar (i.e. general-track and low-achiever) boys as well as similar (i.e. general-track and female) high-achievers. However, it does not close the gap between female low-achievers from a general-track and female low-achievers from a science-track.

Finally, the varying dyad compositions were added to the model as fixed effects because it could be assumed that the way in which dyads are composed might influence students' learning gain after the web-based project. However, adding "dyad composition based on gender", "dyad composition based on achievement level" and the interaction of the two variables into the model did not result in a significant improvement of the model (χ^2 = 5.35, *df* = 8, *p* < .71) and the estimates of the parameters were found not to be significant. Consequently, our results do not indicate that dyad composition is a confounding variable regarding knowledge acquisition after a web-based collaborative inquiry project.

Inquiry skills

The same stepwise procedure was followed to build the models estimating students' inquiry skills and their learning gain after the WISE project. The fixed part of the four-level null model for scientific inquiry indicates that the overall scientific inquiry level on pre-test is 5.89 out of 10. Students' overall improvement of inquiry skills is 1.36, which is found to be significant (χ^2 = 10.64, *df* = 1, *p* < .01). The random part, on the other hand, indicates that the variances on class, dyad, and student level are significantly different from zero regarding the residuals for pre-test scores. The total variance in students' pre-test inquiry performance consists of 29.61% at the class level, 13.97% at the dyad level, and 54.52% at the student level. Regarding students' improvement of inquiry skills, no significant variance is found at the group level, but the total variance consists of 21.74% at the class level and 77.49% at the student level.

Adding the independent variables gender, achievement level and academic track to the model did not result in a better model fit than the null model (χ^2 = 7.78, *df* = 14, *p* = .90). Moreover, none of these variables had a significant main or interaction effect on the scores and did not lead to an improvement in inquiry skills. In other words, all students benefited equally from the project concerning the improvement of their inquiry skills. The same was true when adding the variables based on group composition. According to the previous model explaining knowledge acquisition, group composition was not found to be a confounding variable with respect to students' learning gain in terms of their performance on the inquiry task.

Interest in science

Finally, the models to predict the third dependent variable, that is, interest in science, were built in order to determine individual and group differences with regard to students' pre-test level of interest in science and their potential gains in interest. The fixed part of the four-level null model indicates that the overall interest in science prior to the intervention is 3.44 on a 5-point Likert scale, which is the intercept depicted in Table 3. Moreover, a small but significant improvement of 0.04 (χ^2 = 4.21, *df* = 1, p < .05) in interest in science is found. Based on the random part of the null model, we know that the variance in interest in science prior to the intervention amounts to 22.05% at the class level, 17.77% at the dyad level, and 60.17% at the student level, which are all significantly different from zero at the p < .05 level. The variance in the gain scores for interest in science, however, is only found at the student level.

Table 3
Multilevel parameter estimates for the four-level analyses of students' interest in science

Parameter	Model 0	Model 1
Fixed part		
Intercept	3.44 (0.08)	3.69 (0.09)
Gain in interest	0.04* (0.02)	-0.03 (0.04)
Girl		-0.17* (0.07)
Low		-0.09 (0.07)
General track		-0.57*** (0.15)
Girl*gain in interest		0.12** (0.04)
Low* gain in interest		0.01 (0.04)
General track* gain in interest		0.01 (0.05)
Random part		
Level 4 - Class		
Intercept/intercept (σ^2_{f0})	0.10*(0.04)	0.05* (0.02)
Gain in interest/gain in interest (σ^2_{f1})	0.00 (0.00)	0.00 (0.00)
Gain in interest/intercept (σ^2_{f10})	0.00 (0.00)	0.00 (0.00)
Level 3 - Group		
Intercept/intercept (σ^2_{v0})	0.08** (0.03)	0.08** (0.03)
Gain in interest/gain in interest (σ^2_{v1})	0.00 (0.00)	0.00 (0.00)
Gain in interest /intercept (σ^2_{v10})	0.00 (0.00)	0.00 (0.00)
Level 2 - Student		
Intercept/intercept (σ^2_{u0})	0.28*** (0.03)	0.27*** (0.03)
Gain in interest/gain in interest (σ^2_{u1})	0.14***(0.01)	0.13*** (0.01)
Gain in interest/intercept (σ^2_{u10})	-0.08*** (0.01)	-0.07*** (0.01)
Level 1 – Test time		
Intercept/intercept (σ^2_{e0})	0.00 (0.00)	0.00 (0.00)
Model fit		
-2*log likelihood (Deviance)	802.49	780.20
χ^2		22.29
df		6
p		< .05
Reference model		Model 0

Note. Standard errors are in parentheses. * p<.05 ** p<.01 *** p<.001

By adding the independent variables, we only found significant main effects that resulted in a significant improvement of the model fit (χ^2 = 22.29, *df* = 6, p < .05), as shown in model 1 in Table 3. No significant interaction effects between cross-level variables were found and moreover, adding these cross interactions did not result in a significantly better model. The adjusted predicted means of interest in science across the different groups of students calculated by means of model 1 are depicted in Figure 4. A main effect of gender regarding students' interest in science prior to the intervention was found, indicating that girls' interest in science is significantly lower than that reported by boys. However, we also found a significant main effect for gender regarding improvement of interest in science after the intervention. Girls' gain in interest was slightly, but significantly, higher than that of boys, as depicted in Figure 4. As a consequence, after the intervention, boys and girls report an equal interest in science. Regarding the general-track students, compared to the science-track students, there was only a significant main effect on interest prior to the intervention, which means that general-track students' interest in science was significantly lower than that of science-track students; no difference was found regarding their gain in interest. Finally, regarding the comparison between low-achieving students and high-achieving students, no significant differences were found in students' interest prior to the intervention and their gain in interest.

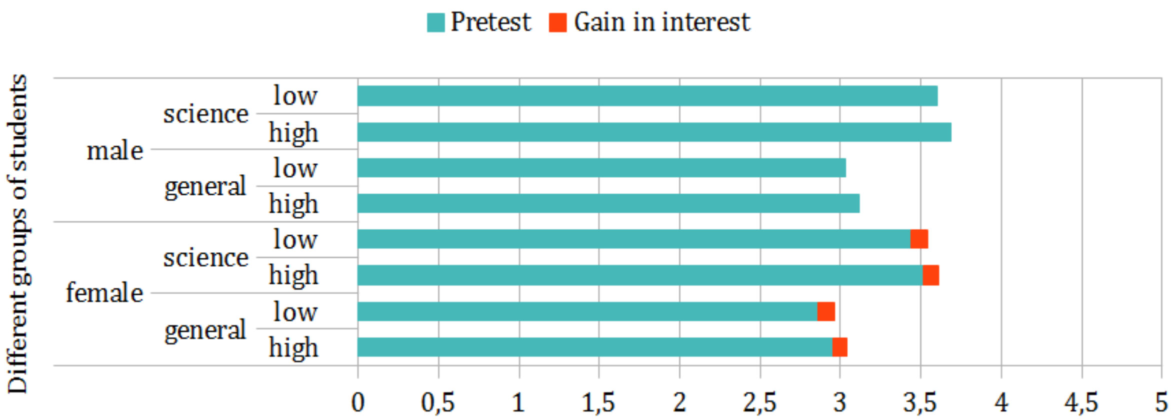

Figure 4. Graphical representation of the adjusted predicted means of interest in science and gain in interest for the different groups of students. The full bar represents the post-test score (5-point Likert scale).

Discussion

Science education has often been considered to play an important role in terms of countering the problem of decreased interest in science and the resulting reduction in the numbers of young people choosing to pursue scientific studies. Nonetheless, most contemporary science classrooms still require students to consume, to complete, and to replicate given knowledge. This "absorption approach" (Linn & Eylon, 2011) is contradictory to how students learn in informal settings, in which they are connected to their peers, to technology, and to the web content in which they are interested. Moreover, science education faces the challenging task of providing adequate instruction to meet the needs of a diversity of students, although research to address this issue is lacking. Based on previous research, it can be stated that some groups are more disadvantaged in science education than others. First, girls are still under-represented in science, which might be related to the fact that girls and boys often experience qualitatively different educational situations due to the stereotypical beliefs related to science as a male domain (Greenfield, 1996). Second, low-achievers in science are disadvantaged because, due to teachers' self-fulfilling prophecy, they are often deprived from engaging instruction which emphasizes scientific reasoning and inquiry-based instruction. The belief that this kind of instruction is only suitable for certain students, especially those with higher cognitive abilities, means that teachers tend to interact less with low-achieving students, leading them to often be "stuck" with learning activities that emphasize knowledge transfer (Zohar et al., 2001; Zohar & Dori, 2003). This finding also holds for a third group, that is students from a general-track, who often receive less challenging instruction, and are subsequently even less motivated to learn science (Oakes, 2005).

To counter this problem, web-based collaborative inquiry learning can be put forth as a promising learning approach in an attempt to make science accessible and interesting to all academic tracks and to rectify the gaps in science education between high- and low-achieving students, and between girls and boys. Although the benefits of web-based collaborative inquiry have already been researched and proven in the past, research with a focus on the potential benefits of this learning approach on these disadvantaged groups in science has been relegated to a lower research priority for many years (Bruckman, 2000). Against this background, in this particular study, a web-based collaborative inquiry project was implemented in real classroom settings in accordance with the knowledge integration approach and the corresponding design principles (Slotta & Linn, 2009) in order to investigate the following hypotheses: First, based on previous research, it was hypothesized that this learning approach can benefit girls' science learning because of the opportunity to share and discuss ideas about science topics connected with everyday life in small groups. Second, it was hypothesized that it can also benefit low-achieving students in science as the knowledge integration approach respects the ideas of all learners and gives all students the opportunity to express their thoughts while working at their own pace. And third, it was hypothesized that this learning approach is suitable and beneficial for science-track as well as general-track students as it can counter the prominent self-fulfilling prophecy. Whereas most previous studies only included one factor in isolation, for instance gender, without taking into consideration the complex situation that arises when these different factors interact, this study tested the main and interaction effects of the predictor variables on the student, dyad and class level by means of a multilevel approach. Multilevel models were built to analyze the effects on three desired outcomes of the web-based inquiry project, that is knowledge acquisition, inquiry skills, and interest in science.

With regard to knowledge acquisition, our study found that all students made significant progress in connecting ideas in their explanations regarding climate change, which resulted in a significant increase in students' conceptual knowledge across all students. This is consistent with previous research showing significant pre- to post-test gains in learning science by means of web-based inquiry learning (e.g. Lee et al., 2010; Slotta & Linn, 2009). Nevertheless, we were particularly interested in the differential effects regarding the benefits. Within this intervention study, significant main effects were found for achievement level and academic track. Low-achieving students and students following a general-track scored significantly lower on the pre-test compared to high-achieving students and students following a science-track. However, these students achieved significantly higher learning gains compared to high-achievers and science-track students. Regarding gender, male and female students did not have significantly different knowledge scores on the pre-test and no significant difference was found in their learning gain. However, a significant three-way interaction, that is girl*low-achiever*general-track was found on the pre-test score as well as on the gain score. This means that although low-achieving girls from the general-track started the project with the lowest pre-test scores, they achieved the highest learning gains. Given the fact that previous research has indicated that girls and low-achieving students often have a lower perceived ability (DeBacker & Nelson, 2000, Greene & Miller, 1996), this finding is promising: It was suggested by Bandura (1986) that, as academic achievement and perceived ability are reciprocally related, higher achievement boosts a student's perceived ability and the resulting greater confidence, in turn, supports the student in striving for and maintaining high achievement (DeBacker & Nelson, 2000). Our results indicate that low-achieving students and students from a general-track, and more specifically low-achieving girls from a general-track, are likely to benefit from web-based collaborative inquiry as an intervention which can elicit these achievement boosts.

The higher learning gains for disadvantaged students might possibly be explained by the integrated design principles which promote knowledge integration (Bell & Linn, 2000). It seems that particularly lower-achieving students may benefit from phenomena in science being made visible and open to discussion (Mayer-Smith et al., 2000; Park et al., 2008; White & Frederiksen, 1998). By applying web-based collaborative inquiry, students can discuss science topics in small groups, which is less threatening than in front of the whole class. In traditional education, by contrast, it is especially the high-achievers who will have the confidence to actively engage in classroom discussions. In this respect, web-based collaborative inquiry can lessen anxiety among low-ability students in science education. Moreover, this teaching approach is less liable to a teacher's self-fulfilling prophecy as every student gets the chance to engage in high-level inquiry learning and to show his/her capacities. Furthermore, students have the opportunity to work at their own pace and those who fall behind can receive individualized attention from the teacher. Another explanation for the fact that some students benefit more from web-based collaborative inquiry than others may possibly lie in the engagement in effortful learning. In web-based collaborative inquiry learning, knowledge acquisition is more likely to occur if students engage in new information at a sufficiently deep level to recognize conflicts between existing information and new information; however, this kind of learning needs persistence and effort. Research by Leong and Hawamdeh (1999) which focused only on the gender issue and learning attitudes in using web-based collaborative science lessons found differences in same-gender group dynamics. Girls tended to be more co-operative in the groups and invested more effort compared to boys. In this respect, by emphasizing effortful learning, teachers can facilitate a sense of control in students over their own learning. DeBacker and Nelson (2000) indicated that this sense of control is particularly important for students who struggle at school and are at risk of developing learned helplessness, in the sense that they are helpless in the face of academic failure. Consequently, web-based collaborative inquiry can help students to attribute successes to controllable factors, that is active and effortful learning. While the study by Leong and Hawamdeh (1999) compared same-gender groups, in our study, students were able to choose whom they worked with, which resulted in same- and mixed-gender dyads. Although previous research has found gender-pairing to be a significant factor in a group's problem-solving learning in CSCL (Ding, Bosker, & Harskamp, 2011), this was not confirmed in the present study.

Besides knowledge acquisition, the intervention in this study aimed to promote an atmosphere of inquiry and investigated whether students' inquiry skills were enhanced after the web-based inquiry science project. Inquiry skills were measured by focusing on identifying the research question, hypothesis generation, and planning of an investigation. Students' scores on the inquiry test significantly improved. Nevertheless, no significant effects were found regarding the variables gender, achievement level and academic track, meaning that there is no differential increase for these groups of disadvantaged students. Students benefited equally from web-based inquiry learning.

Finally, this intervention aimed to improve students' interest in science by eliciting and respecting the ideas of all learners and enhancing challenge, variety, and choice through worldwide access to numerous sources of information (Blumenfeld, et al., 1991; Nieswandt & Shanahan, 2008). Our results indicate that implementing web-based collaborative inquiry in classroom settings can trigger positive changes in some students' interest in science. Interestingly, a slight but significantly positive change in interest in science was found for female students. Although girls started the project with a significantly lower interest in science, the girls achieved the highest gain in interest in science, consequently narrowing the gap between girls and boys on the post-test. In this context, previous researchers (Bennett et al., 2007; Park et al., 2008; Slotta & Linn, 2009) recognized that when students are able to link science knowledge to everyday life, science knowledge becomes relevant, and attitudes are positively affected. In addition, it is found that girls are more likely to attach value to the social context of learning (Leong & Hawamdeh, 1999; Murphy & Whitelegg, 2006).

Limitations and implications for further research

A first methodological limitation of the current study design is the absence of a control group. A control group design would have allowed us to test whether the effects found in this study can definitely be attributed to the web-based collaborative inquiry in science education. Besides this, it would allow aptitude treatment interactions (ATI) to be tested, a concept that is based on the assumption that some instructional strategies (treatments) are more or less effective for particular individuals depending upon their specific abilities (Cronbach & Snow, 1977). Another limitation is related to the fact that this study took place in real classrooms and was conducted on (relatively) large scale. Although researching authentic settings is advantageous due to the high ecological validity, there are some inherent drawbacks. As the intervention was conducted on a large scale and in a real-life context, the available time and facility to measure learning processes was limited. This quantitative research only presented individual learning outcomes; in order to further improve the results in terms of closing the gaps in secondary science education, additional (qualitative) research needs to provide more insight into the learning processes, that is how actively these disadvantaged groups participate in this changing learning environment and how these students interact with the teacher, their peers and the technology-enhanced learning environment. Furthermore, Master's students in the Educational Sciences program were closely involved in the implementation and conducted the questionnaires and tests. However, future research should include real classroom teachers in order to gain insight into the effects of teachers' behavior during web-based collaborative inquiry learning, and to investigate whether teachers are indeed less liable to a self-fulfilling prophecy in this computer-supported collaborative learning setting compared to a traditional classroom setting. In addition, we have to acknowledge that the development of attitudes toward science is an ongoing process (Machina & Gokhale, 2010). Although the present study provides positive and promising results, it should be recognized that in order to maintain positive attitudes toward science and to ensure that young people are open to participating in science in higher education, an isolated inquiry project addressing a single science topic may not be sufficient. We need to investigate web-based inquiry learning for more extended periods of time and across different science topics. In this respect, professional development to enable teachers to integrate these classroom strategies, that is collaboration, inquiry and technology-enhanced learning, into their everyday science teaching is needed. Moreover, further research should reach more students from a general-track. As we were dependent on the willingness of the respective school board to participate in the research project, our sample was somewhat skewed. Teachers were particularly willing to participate in the project with students from their science-track class, as this track provides more time for such activities. This is contradictory in view of the fact that this learning approach offers advantages particularly for students who are not typically successful in science.

Conclusion

Although different kinds of collaborative inquiry have been widely researched in the Learning Sciences, this study addressed three research gaps: 1) The main focus of the study was on the benefits of web-based collaborative inquiry learning for three disadvantaged groups: girls, low-achievers, and general-track students - a focus that has been relegated to a lower research priority for many years; 2) the research project implemented web-based collaborative inquiry in an authentic science classroom; and 3) effects were measured on a (relatively) large scale, with 370 students from 19 secondary school classes, and were analyzed using multilevel analysis.

This study thus represents an important step in providing new quantitative evidence that implementing a web-based collaborative inquiry project in science education using a knowledge integration approach is not only an effective approach for science learning, but also that this instructional approach can particularly benefit disadvantaged students in science who are not typically successful in science or not enrolled in a science-track. It is found that this learning approach can contribute to the aim of narrowing the gap between boys and girls in science learning and can give low-achieving students in science and general-track students an opportunity to develop confidence and skills for learning science, which can bring them to a performance level that is closer to that of high-achieving students. Eliciting and respecting the ideas of all learners and embracing the internet as an information resource which creates the opportunity for students to pursue questions of personal interest seems helpful in supporting more diverse students in their learning of science and can work against (gender) stereotypes that often discourage disadvantaged groups from participating in science.

Acknowledgements

We wish to thank the reviewers and more particularly Nikol Rummel who acted as the Associate Editor during the review process of this manuscript for her thoughtful and fruitful feedback which improved this manuscript through the different rounds of revision. We are also thankful to James Slotta who introduced us to WISE and the Knowledge Integration approach and Marcia Linn who gave Annelies Raes the opportunity to visit UC Berkeley as a Visiting Student Researcher and get acquainted with the Technology-Enhanced Learning in Science (TELS) Research Community.

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Appendix A

Exemplary test items

Knowledge items	-What is the difference between weather and climate? Explain. -What is the IPCC?
Explanation item	Which part of figure B is comparable with the glass on figure A. Thick the right answer and explain your answer. ☐ The sun ☐ The cosmos ☐ The atmosphere  Figure A  Figure B

Appendix B

Scoring Rubric for knowledge items

Grade / score	Response description
0	Students have no or incorrect and irrelevant ideas in the given context.
1	Students have some relevant and correct ideas but do not connect them in a given context. There are still incorrect and irrelevant ideas included in the answer.
2	The answer is correct, but rather isolated. Students still fail to connect the relevant ideas.
3	Scientific concepts are explained correct and coherent as a token of a systematic understanding.

Appendix C

Scoring Rubric for explanation items

Grade / score	Response description
0	Students have no or incorrect and irrelevant ideas in the given context.
1	Correct multiple choice answer, but without further explanation.
2	Correct multiple choice answer with further explanation, but rather isolated and still some incorrect and irrelevant ideas are included.
3	Students have correct and relevant ideas but do not fully elaborate links between them in the given context. They still fail to connect the relevant ideas.
4	Students recognize connections between scientific concepts and understand how they interact. They have a systematic understanding and apply this in their explanation and argumentation.

3 Scaffolding information problem solving during web-based collaborative inquiry learning

This chapter is based on:

Raes, A., Schellens, T., De Wever, B. &. Vanderhoven, E. (2012). Scaffolding information problem solving in web-based collaborative inquiry learning. *Computers & Education, 59;* 82-94. doi: 10.1016/j.compedu.2011.11.010

Chapter 3
Scaffolding information problem solving during web-based collaborative inquiry learning

Abstract

This study investigated the impact of different modes of scaffolding on students who are learning science through a web-based collaborative inquiry project in authentic classroom settings and explored the interaction effects with students' characteristics. The intervention study aimed to improve domain-specific knowledge and metacognitive awareness during online information problem solving (IPS) as part of an online inquiry project. Three experimental conditions (teacher-enhanced scaffolding, technology-enhanced scaffolding, and both forms of scaffolding) were compared with a control condition in a two-by-two factorial quasi-experimental design. Moreover, gender and prior knowledge were examined as two factors which may have a significant impact on Web-based learning. In a four-week field study in secondary science education, pre- to post-test differences were measured. In total 347 students from 18 secondary school classes were involved and the classes were randomly distributed over the 4 conditions. Our findings support the notion of multiple scaffolding as an approach to enhance both knowledge acquisition and metacognitive awareness with respect to IPS-processes and to meet a mix of students with different needs within the context of a web-based inquiry learning project.

Introduction

Information and computer technologies and more specific the World Wide Web are receiving increased attention in education because of their potential to support new forms of (collaborative) inquiry (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). When the World Wide Web is used as a source within inquiry learning this supports the development of higher-order skills such as critical thinking and problem solving (Linn, Clark, & Slotta, 2003). But, although learning in such dynamic learning environments is much more engaging, learning is also much more challenging (Kuiper, Volman, & Terwel, 2009). Many students experience difficulties when receiving learning tasks that require them to find answers on the Internet or to retrieve information for the construction of arguments that can be used in scientific debates (Raes, Schellens, & De Wever, 2010). This set of activities, conceptualized as Information Problem Solving (IPS) on the Web (Brand-Gruwel, Wopereis, & Walraven, 2009), is only a part of what web-based inquiry learning can include but it can be seen as a prerequisite for successful web-based inquiry learning.

Since the World Wide Web is an extensive source of information, strong self-regulation ability and metacognitive awareness are necessary in order to be successful in web-based learning (Brand-Gruwel et al., 2009). However, contemporary cognitive and educational research has shown that most students have difficulty regulating their learning as well as performing metacognitive activities spontaneously (Lazonder & Rouet, 2008). In this context the mechanism of scaffolding, offering students an adaptable support system during the learning process, is put forth as a condition for acquiring the self-regulatory skills that IPS entails (Lazonder, 2001). Yet, while traditional scaffolding research focused on one type of scaffolding, particularly computer-embedded prompting (Azevedo & Hadwin, 2005; Reiser, 2004), few studies have documented interactions among multiple modes of scaffolding in real classroom settings (Kim & Hannafin, 2011). To help fill this gap, this study provides insight into the unique value of two different modes of scaffolds, technology-enhanced and teacher-enhanced scaffolding, to support knowledge acquisition and information problem solving as part of a web-based collaborative inquiry project. Before explaining the methodology of this study, the two key concepts "information problem solving on the web" and "the notion of scaffolding" will be described.

Information Problem Solving on the Web

The concept of Information Problem Solving (IPS) combines the skills needed to access and use information, whether or not found on the Internet (Brand-Gruwel et al., 2009; Eisenberg & Berkowitz, 1990). Yet, within this study, we only focus on IPS while using the Web. Within web-based inquiry learning students are often confronted with problems for which information is required to solve it (Brand-Gruwel et al., 2009). Understanding how students engage in the IPS-process is becoming an increasingly important area of research in library and information sciences (Eisenberg & Berkowitz, 1990; Kuhlthau, 2004) and in learning and educational sciences (Kuiper et al., 2009; Walraven, Brand-gruwel, & Boshuizen, 2009; Wecker, Kohnlet, & Fischer, 2007).

Within this research, the model of Brand-Gruwel and colleagues (2009) is used as a comprehensive framework to conceptualize students' IPS while using the Web. Moreover it is used as an external script that guided the design of the scaffolding during the intervention which is described below. This model, depicted in Figure 1, describes the main skills, regulation skills, and conditional skills needed to solve information problems. Based on this model, it is assumed that students need to master the following main skills: "Define the information problem", "Search information", "Scan information", "Process information", and "Organize and present information". Second, to be successful in IPS, a strong appeal to peoples' regulation ability is made during the execution of all skills. Regulatory aspects such as orientation, monitoring, steering, and evaluation, are crucial in the execution of the skill. Finally, students are assumed to have the adequate reading, evaluating, and computer skills, which are the conditional skills.

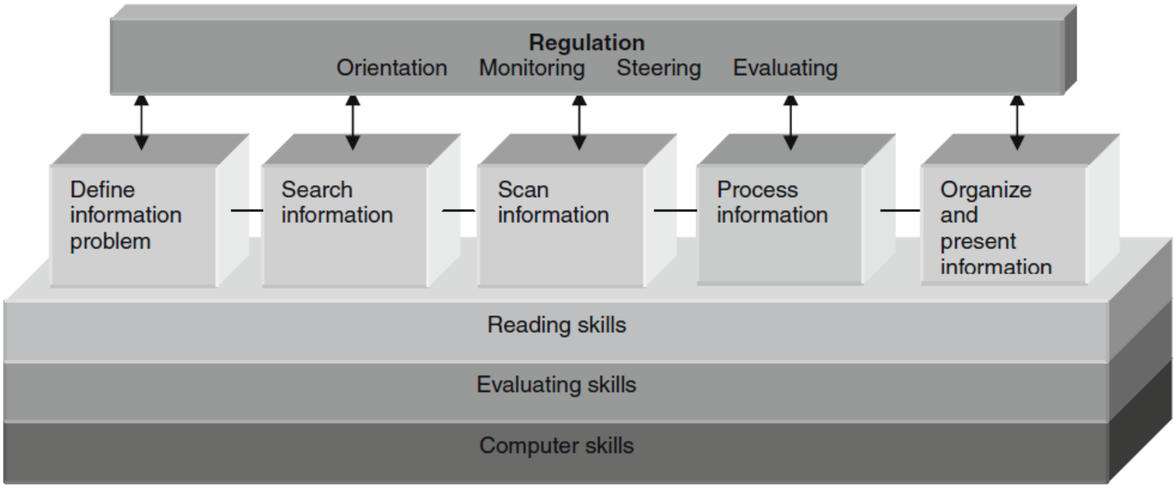

Figure 1. The information problem solving using internet model (IPS-I-model) from "A descriptive model of information problem solving while using internet." by S. Brand-Gruwel, I. Wopereis, and A. Walraven, 2009, Computers and Education, 53, p.1209.

Numerous studies on IPS have found that when attempting to self-regulate their learning, students predominantly use ineffective strategies and rarely engage in help-seeking behavior (Azevedo, Cromley, & Seibert, 2004). Teenagers, for instance, use information that can solve their information problem without thinking about the purpose of a website (Fidel et al., 1999) and they hardly evaluate information results and information sources (Walraven et al., 2009).

A state-of-the art study of Chen and Macredie (2010) reviewed the empirical studies that examined how human factors affect user's interactions with the web, accounting for gender differences and prior knowledge. Regarding gender, some studies (e.g. Koohang & Durante, 2003) found that there are no gender differences in navigation patterns and attitudes toward web-based interaction, but the majority of studies (e.g. Large, Beheshti, & Rahman, 2002; Liu & Huang, 2008; Roy, Taylor, & Chi, 2003) indicated that females and males showed different behavior and demonstrated different attitudes. In particular, females encountered more disorientation problems, they generally felt themselves unable to find their way around effectively and they were more likely to get lost compared to males (Ford, Miller, & Moss, 2001). With regard to different levels of prior knowledge, several studies argue that this factor can play a substantial role in Internet searching. User's prior knowledge can include system experience and domain knowledge. The former refers to user's knowledge of the system being used whereas the latter refers to user's understanding of the content area (Lazonder, 2000). Only the latter is taken into account in this study. Regarding domain knowledge, it is found that domain experts issued longer queries and used many more technical query terms compared to domain non-experts (White, Dumais, & Teevan, 2009). Moreover, it is found that novices used significantly fewer meta-cognitive strategies than intermediates or experts (Tabatabai & Shore, 2005) found.

Since the development of metacognitive awareness is considered to be the key to successful learning (Flavell, 1976), it is important to focus on how we can improve this metacognitive awareness. Metacognition is classically divided into two major components that are metacognitive knowledge and metacognitive regulation. The former can be simply explained by knowledge about cognition while the latter can be referred as the way for regulation of cognition (Schraw & Moshman, 1995). Knowledge about cognition on the one hand is defined as an awareness of one's strengths and weaknesses, knowledge about strategies and why and when to use those strategies. Regulation of cognition on the other hand is defined as a number of sub processes that facilitates the control aspect of learning, i.e. planning, information management, comprehension monitoring, and evaluation (Schraw & Dennison, 1994). Subsequently, to improve this metacognitive awareness is has been found that students need activities that incorporate reflection, thinking about what they are going to do and why. To develop thinking implicit, explicit scaffolding is needed.

The notion of Scaffolding

The notion of scaffolding comes from the socio-constructivist model of learning (Vygotsky, 1978) and was traditionally introduced by Wood, Bruner, and Ross (1976) who believed that learning occurs in one-on-one interactions in which a more knowledgeable person guides a learner's emerging understanding. In accordance with Vygotsky's zone of proximal development, the scaffold should provide just enough information so that the learner may make progress on his or her own (Hogan & Pressley, 1997). However, the modern classroom does not allow that privilege, since a teacher cannot interact with every child or small group individually. Consequently, teacher's help is usually not based on what any individual requires at the moment, but rather on what the teacher believes the class needs in order to be successful (Davis & Miyake, 2004). In recent project-based approaches to learning, ways to use various forms of support provided by software tools have therefore been explored (Davis & Miyake, 2004; Reiser, 2004).

In the most common approach to technology-enhanced support, embedded computer-based scaffolds guide and support individuals or small groups through their inquiry processes (Morris et al., 2010). However, these embedded tools cannot include the dynamics of face-to-face interactions, they are more static which means that the amount and type of support is fixed. Dynamic scaffolding, however, is based on observation and ongoing diagnoses and provides support in a personal way (Puntambekar & Hubscher, 2005).

Based on these findings, it is assumed that supporting multiple students in a technology-enhanced classroom requires a rethink of the notion of scaffolding (Luckin, Looi, Chen, Puntambekar, & Stanton Fraser, 2011). In this respect, distributed scaffolding with multiple modes of support with each its own unique affordances is put forth as an approach to support learning in complex classrooms (McNeill & Krajcik, 2009; Puntambekar & Kolodner, 2005; Tabak, 2004). However, as indicated by Kim and Hannafin (2011), research that explores everyday classroom interactions between multiple modes of scaffolding is still limited.

Multiple modes of scaffolding

Within this research two modes of scaffolding, depicted in Table 1, are examined and further explained below.

Table 1
Two modes of scaffolding described according the three dimensions of Scaffolding Problem Solving Inquiry (Kim & Hannafin, 2011): source, interaction, and purpose.

Technology-enhanced scaffolds	**Teacher-enhanced scaffolds**
	
<u>Source:</u> Embedded hints and question prompts which appeared on screen associated with each information problem task	<u>Source:</u> Cues en prompts given by the teacher or human tutor who circulated in the classroom
<u>Interaction:</u> Static and fixed, faded over time	<u>Interaction:</u> Dynamic and adaptive based on students' needs while working on the task
<u>Purpose:</u> Metacognitive and strategic: regulating their information-problem solving processes	

Technology-enhanced scaffolding

Prompting to support (self-regulated) learning is gaining recognition as an important instructional scaffolding method, and an increase in usage is most evident in the field of computer-based learning environments (Bannert, 2009). Prompts are defined as measures to induce and stimulate cognitive, metacognitive, motivational, and/or cooperative activities during learning, which vary from hints, suggestions, reminders, sentence openers to questions (Morris et al., 2010). Within technology-enhanced learning environments, these can be displayed on screen at certain times in the learning process. Generally, they are based on the central assumption that students already possess some procedural knowledge about specific tasks, but do not recall or execute them spontaneously (Bannert, 2009). Research provides evidence that it is possible to improve individual learning in a technology environment by implementing appropriate question and reflection prompts that trigger students to activate their cognitive processes (Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008).

However, studies have found that simply prompting students to use strategies of IPS does not always lead to improvements in learning outcomes and web literacy (Lazonder & Rouet, 2008; Stadtler & Bromme, 2007). Learners may need further support to take advantage of the opportunity to self-regulate their performance, e.g. by means of distributed monitoring (Wecker & Fischer, 2010) or human guidance (Azevedo, Moos, Greene, Winters, & Crornley, 2008) which is taken into account as a second mode of support.

Teacher-enhanced scaffolding

According to Crawford (2000) teachers play multiple roles in inquiry classes. Moreover, when the inquiry classes are technology-enhanced, teachers' roles become even more crucial. The teacher needs to first help students understand the inquiry practice before they can effectively use the computer-based scaffolds embedded in the project (Pea, 2004). Moreover, the teacher needs to acts as an adaptive scaffold that facilitates students' IPS by prompting students to deploy certain key processes and strategies during web-based learning. Providing students with an external regulating agent, i.e. the teacher or a human tutor, is proved to be more beneficial than when students only need to self-regulate their learning (Azevedo et al., 2008). Consistently, research on metacognitive tools has underlined the significance of adaptive, human scaffolding in facilitating science learning with technologies (Kim & Hannafin, 2011).

Interaction between scaffolding and students' characteristics

Since it has been found that gender and prior knowledge may have a significant impact on web-based learning and Internet searching (Chen & Macredie, 2010), it can be questioned to what extent the effect of scaffolding web-based IPS-processes is also influenced by those individual differences. Previous research indicated that learners who lack adequate prior knowledge may be more limited – or even fail - to adequately perform problem solving processes; consequently these students especially need a teacher or human tutor who can scaffold or model inquiry (Kim & Hannafin, 2011, Kirschner, Sweller, & Clark, 2006). According to Zohar and Peled (2008) explicit teaching of metastrategic knowledge is a vital instructional method especially for supporting the progress of students with low-academic achievements.

Although web-based inquiry learning is demanding for students, it has been indicated that students often refrain from seeking help from the sources (e.g. teacher, peer learners, computer) available in a classroom (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003). Moreover, there are indications that help-seeking behavior is influenced by gender since it have been found that females are more willing to seek help in the classroom when they need it (Ryan, Pintrich, & Midgley, 2001).

Chen and Marcredie (2010) put forth that it is important to be aware of such differences since offering appropriate support to each individual may result in the improvement of student performance. Yet, in most scaffolding research these individual differences are not taken into account (e.g. Wang, Kollar, Stegmann, & Fischer, 2011).

Research questions

Two main research question drove this study:

1. Was is the impact of multiple modes of scaffolding on students' domain-specific knowledge and students' metacognitive awareness during information problem solving?
2. Does the way students are scaffolded interact with students' personal characteristics, i.e. gender and students' level of prior knowledge?

The multiple modes of scaffolding were investigated in a two-by-two factorial quasi-experimental design with three experimental conditions (teacher-enhanced scaffolding, technology-enhanced scaffolding, and both forms of scaffolding) and a control condition.

Method

Study participants

The participants in this study were 347 students from 18 secondary school classes, grade 9 and 10 from 10 Flemish secondary schools. The average age of these students was 16 years (*SD* = 0.56); 178 of them were girls (51.3%), 169 were boys (48.7%). A group of 17 science teachers were involved in the research project. Teacher participation in the intervention was voluntary and teachers agreed to dedicate four lessons of 50 minutes for involvement in the research project.

Instructional context and curriculum project

This study was conducted in the context of a web-based inquiry science project in secondary education. Consistent with a previous study (Raes et al., 2010) global warming and climate change was chosen as the topic under investigation. This is an issue that students have heard about, but because of the uncertainty and controversy in the scientific community about the scientific issues associated with climate change, global warming and climate change can be considered as a complex topic. The web-based inquiry project that spanned four regular science lessons was implemented during a four-week field study in secondary education.

The Web-Based Inquiry Science Environment (WISE) (Slotta & Linn, 2009) was used in this study to design our project. WISE is developed to provide a solid online platform that allows teachers to adopt new forms of inquiry-based instruction. For students, on the other hand, it is a powerful learning environment where they examine in dyads real world evidence from the web and analyze current scientific controversies. The project was learning goal driven, which means that learning goals identified from the national science standards have guided all phases of the project design. Besides the science content, other learning goals strongly focused on information problem solving (i.e. search, select, gather, and use web info as evidence to support their claims and answers). The design of this project is in accordance with previous research suggesting that a whole-task approach with embedded instruction that promote IPS within inquiry activities is effective for teaching the highly interrelated constituent skills and sub skills involved in IPS (Lazonder & Rouet, 2008). Moreover, valuable insights from the notion of scaffolding, i.e. the growing body of opinion that fading is a fundamental and intrinsic component of scaffolding (Pea, 2004; Puntambekar & Hubscher, 2005), were applied within the overall project. Table 2 gives an overview of how the notion of fading was operationalized within the designed project.

Table 2
Operationalization of the notion of fading within the WISE-project

	Start of the project	**→**	**End of the project**
#1 Task Definition	Straightforward e.g.: What's the difference between weather and climate?	More complex e.g.: Why are the sun, atmosphere, oceans and the earth surface the main protagonists of the climate?	Advanced e.g.: A common skeptic argument is that climate has changed naturally in the past, so humans cannot be causing global warming now. Respond to this with a scientifically valid argument.
#2 Information Seeking Strategies	The search space is restricted by providing a list of pre-selected websites (max. 3) on which students can find the answers	Only one important and reliable source is provided, students need to add information they search on the WWW.	No sources are provided, students need to search the WWW to solve the information problem.
#3 Location & Access	Students need to judge the relevance of the sources to answer the question.	Students need to judge the relevance of the provided source and judge the relevance and reliability of found sources	Students need to judge relevance and reliability of the found sources
#4 Use of Information	Due to a more simple information problem, students can find the answer on the provided websites.	A more complex information problem require students to add information from different websites.	Multiple sources need to be find and combined to construct a valuable answer.
#5 Synthesis of information	A sentence opener is provided in the body of the answer input box: e.g."The difference between weather and climate is…" and the given sources are already mentioned	No sentence opener is provided, but students are prompted within the answer input box to formulate their sources.	No scaffolds were provided within the answer input box to remind students about the information problem and about mentioning the used sources.

During the project, students navigated through the sequence of inquiry activities using the inquiry map in the WISE environment and they were asked to write their answers down in input boxes embedded in the web-based project. Students also worked in the same dyads during the whole intervention since collaborative inquiry has been found to positively relate to self-regulation, as well as yielding higher learning outcomes during web search compared to individual work (Lazonder, 2005).

Study Design

As shown in Figure 2, three experimental conditions were compared with a control condition in a two-by-two factorial quasi-experimental design. Participating classes were randomly assigned to one of the four conditions, but we ensured that teachers with multiple classes were assigned to the same condition to avoid confusion and conflicts.

		TECHNOLOGY-Enhanced	
		Absent	Present
TEACHER-Enhanced	Absent	Condition 1: **Without scaffolds** (N=63)	Condition 2: **Technology-enhanced scaffolds** (N=72)
	Present	Condition 3: **Teacher-enhanced scaffolds** (N=97)	Condition 4: **Teacher – and technology-enhanced scaffolds** (N=101)

Figure 2. Quasi-experimental 2 x 2 factorial design

Procedure

Forty Master's students in Educational Sciences were involved in this study to support the implementation of the web-based collaborative inquiry project and to act as teachers/human tutors during the project. The Master's students were randomly divided over the 18 classes participating in this study. To be fully prepared, all Master's students went through a thorough training depending on the condition to which they belong. First, different interaction patterns were proposed and discussed based on video excerpts of previous field studies. Second, Master's students practiced their tutoring skills while exercising with their classmates during the test phase of the WISE-project. The instruction for intervention differed from condition to condition and in each condition a strict protocol had to be followed. Although all Master's students were instructed to provide technical and organizational help, the Master's students in the conditions with teacher-enhanced scaffolding (3 and 4), needed to act additionally as external regulating agents. In these conditions extra support was given through metacognitive interventions. Master's students were instructed to interact with groups of students to monitor their IPS process, e.g. asking questions that stimulate students' reflection, probe students' thinking and asking students questions that push them to clarify and elaborate on their ideas, prompting students to focus on particular issues, asking tentative questions to suggest alternative perspectives, without giving the solution procedure. They were instructed to avoid giving answers and providing students with content knowledge. In the conditions without teacher-enhanced scaffolding (1 and 2), Master's students were instructed to avoid providing the pupils with metacognitive and strategic prompting.

Because this adaptive behavior task is extremely complex for teachers, especially since they have to closely monitor group and individual progress (Schwarz & Asterhan, 2010), the Master's students were provided with a tutoring script, a predefined protocol designed to help them manage and scaffold information problem solving during web-based inquiry. The IPS-framework (Brand-Gruwel et al., 2009) presented in the conceptual framework was used to script the scaffolds provided by the Master's students and was also used for designing the technology-enhanced embedded scaffolds. As shown in Table 3, the IPS framework describes as an external script how to fulfill the series of steps for successful information problem solving.

Table 3
IPS tutoring script and corresponding hints & prompts with regard to each constituent skill and sub-skill involved in Information Problem Solving

IPS-skill decomposition	Corresponding scaffolds
#1 Task Definition 1.1 Define the information problem 1.2 Identify information needed	- What does your teacher want you to do? - Restate/rewrite the assignment in your own words - Activate prior knowledge - What information do you need to include in your answer?
#2 Information Seeking Strategies 2.1 Determine all possible sources 2.2 Select the best sources	- Consider the possible sources of information that will help you answer the question - Think about relevant keywords and specify search terms - Evaluate/judge the list of sources.
#3 Location & Access 3.1 Locate sources (intellectually and physically) 3.2 Find information within sources	- Figure out where you will find these sources, read information global - Try to find **relevant** and **useful** sources: Look at the title, index and date. Scan the information using your keywords from step 2 - Try to find **reliable** sources: what is the aim of the website? Who is the writer of the website? Do you find information that confirm the information?
#4 Use of Information 4.1 Engage 4.2 Extract relevant information	- Read, view, or listen to the sources you located during step 3. - Compare information from multiple sources - Take notes to answer the questions you formulated in the first step - Try to paraphrase or summarize ideas instead of just copying information word-for-word from your sources. - Be sure to give credit to your sources.
#5 Synthesis 5.1 Organize from multiple sources 5.2 Present the information	- Structure relevant information and outline your answer. - Is your answer more than just a summary of other people's ideas? - If you paraphrased or summarized information found on the Internet, or from other people, did you cite the source at point of use in your answer (using a footnote or parenthetical reference)?

To warrant - as far as possible - for controlled circumstances, manipulation checks were included to assess whether the conditions were successful put into practice. First, the real classroom teachers – without knowing to which condition they belong – were asked to observe the Master's students and fill out an evaluation form evaluating the overall web-based project, as well as the quality of the intervention of the Master's students. This form of manipulation check informed us on how the Master's interacted in the classroom. Second, the Master's students were required to keep a logbook and additionally they were invited individually for an evaluation talk.

Measurements

In this study, the effects of multiple scaffolding conditions were measured through a pre- and post-test design. During the first session, secondary students completed the individual pre-test and started in dyads the first introductory activity of the WISE-project. The whole project consisted of four main activities considering global warming issues. At the end of the project all students completed the individual post-test. In our analysis of students' learning, we examined *domain-specific knowledge* of the subject global warming and *metacognitive awareness* during IPS, which are the two targeted learning outcomes of the intervention.

Domain-specific knowledge

The pre- and post-achievement test to investigate the learning effect on domain-specific knowledge consisted of eight assessment items (see Appendix A). It was a combination of four open-ended knowledge questions (rubric 0-3) and four multiple-choice items, in which students were asked for explanation and connecting scientific ideas in their arguments (rubric 0-4). The items were scored using an adapted version of the knowledge integration rubric that rewards both accurate and connected ideas, created by the Technology Enhanced Learning in Science Community (TELS, 2010). The rubrics which are displayed in Appendix B and C contain a number of proficiency levels; the higher the proficiency level, the more complex the skills are that the students have to master to tackle the scientific problems. The eight assessment items were added up to form the scale for domain-specific knowledge with a possible range from 0 to 28. The fourth author was trained to use the rubrics and coded all students' answers. 20 % of students' performance was re-coded by a second rater to check for interrater reliability by means of Krippendorff's alpha (Hayes & Krippendorff, 2007). Regarding all the items, Krippendorff's alpha ranged from 0.65 to 1 which indicates good to excellent agreement.

Metacognitive awareness

Because we aimed to improve students' metacognitive awareness during IPS-processes students in pre- and post-test were faced with an unfamiliar information problem, more specifically a scientific controversy (i.e. "Mobile phone radiation: harmful or nonsense?" and "Is nuclear power a good alternative?"). They were assigned to take up a particular position that they needed to justify with appropriate evidence from the web to support their claim. After performing this IPS-task students were asked to fill out an adapted version of the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994). This self-report inventory was used to measure students' perception about their metacognitive and strategic activities while performing the task. The original MAI inventory developed by Schraw and Dennison (1994) consisted of 52 items supporting the two-component view of metacognition, i.e. knowledge of cognition and regulation of cognition. Because the available time was limited, we decided to reduce the number of items. In line with the research of van Schooten (2008), the items with a factor loading on both factors or without factor loading were excluded. This resulted in the adapted inventory which consisted of 40 items. Moreover, these items were transformed to task-specific items related to the information problem solving task on the web. Instead of a 100-mm bi-polar scale, we used 4-point Likert scale that forced students to indicate whether they agree or not with the items concerning the task they previously performed.

The instrument was afterwards evaluated using factor analyses. The forced oblique two-factor solution resulted in loadings on factor 1: knowledge of cognition and factor 2: regulation of cognition. Items with loadings of less than 0.30 and items with cross loadings were excluded. Finally this resulted in 17 items for the knowledge of cognition scale (Cronbach's alpha in pre-test 0.845, in post-test 0.849) and 15 items for the regulation of cognition scale (Cronbach's alpha in pre-test 0.847, in post-test 0.844). See Appendix D for example items of the two components of the Metacognitive Awareness Inventory (Schraw & Dennison, 1994).

Statistical analysis

One-way analyses of covariance (ANCOVA's) were conducted with post-test scores as dependent variable, condition as independent factor, and pre-test scores as covariate to discover whether there are differences between conditions on the post-test measure, after adjustment for the pre-test scores. Moreover the between-subjects factors gender (female versus male students) and prior knowledge based on pre-test scores (high versus low based on mean (7.66) split) are included in the model as independent variables. The Bonferroni test, which corrects for the number of pairwise tests, was used to compare main effects. The significance level was .05 for all analyses.

Results

Students' domain-specific knowledge about climate change

First, the effects of different scaffolding conditions on students' domain-specific knowledge were explored. An overall increase between pre- and post-test was found with respect to students' domain-specific knowledge about climate issues ($F(1,302) = 773.94$, $p < .001$). Yet, ANCOVA confirmed that the four conditions significantly differ on the post-test scores, after adjustment for pre-test scores ($F(3,332) = 12.59$, $p < .001$). Pairwise comparisons indicated that both the condition with teacher-enhanced scaffolds (mean difference = 2.02, $p < .001$) and the condition with teacher-enhanced scaffolds in combination with technology-enhanced scaffolds (mean difference = 1.97, $p < .001$) significantly differ from the control condition. This means that students in these conditions significantly outperform students from the control condition without scaffolds. The difference between the control condition and the condition with technology-enhanced scaffolds was not significant (mean difference = 0.88, $p = .551$).

Moreover we examined how the different scaffolding conditions interact with gender and students' prior knowledge. The post-test scores were analyzed using a factorial analysis of covariance with three between-participant factors: scaffolding condition, gender and prior knowledge. This analysis revealed that the main effect due to the scaffolding condition was significant ($F(3,286) = 5.77$, $p = .001$, partial $\eta^2 = .057$). Moreover a significant main effect was found due to gender ($F(1,286) = 4.48$, $p = .035$, partial $\eta^2 = .015$), whereas the main effect of prior knowledge was not significant ($F(1,286) = 1.29$, $p = .257$, partial $\eta^2 = .004$). Nevertheless, the analysis revealed a significant interaction between prior knowledge and scaffolding condition ($F(3,286) = 2.66$, $p = .048$, partial $\eta^2 = 0.027$) which suggest differential effects depending on students' prior knowledge. Additionally, the interaction between gender and scaffolding condition is found to be marginally significant ($F(3,286) = 2.47$, $p = .063$, partial $\eta^2 = .025$). No significant interaction was found between prior knowledge and gender ($F(1,286) = 0.24$, $p = .625$, partial $\eta^2 = .001$). The three-way interaction was not significant ($F(3,286) = 0.63$, $p = .591$, partial $\eta^2 = .007$). The interactions with gender and prior knowledge are further explained with reference to the plots presented below.

Interaction with gender

The observed means for post-test scores, after adjustment for the pre-test, for boys and girls in the four scaffolding conditions are presented in Figure 3. According to the main effect of gender, it is found that female students significantly outperform male students regarding domain-specific knowledge after the WISE-project (mean difference = 0.78, $p = .035$). However, this outperformance of girls does not count in every scaffolding condition. When students are provided with teacher-enhanced scaffolds, boys and girls perform equally. The combined condition, however, seems to result in higher post-test performance for female students.

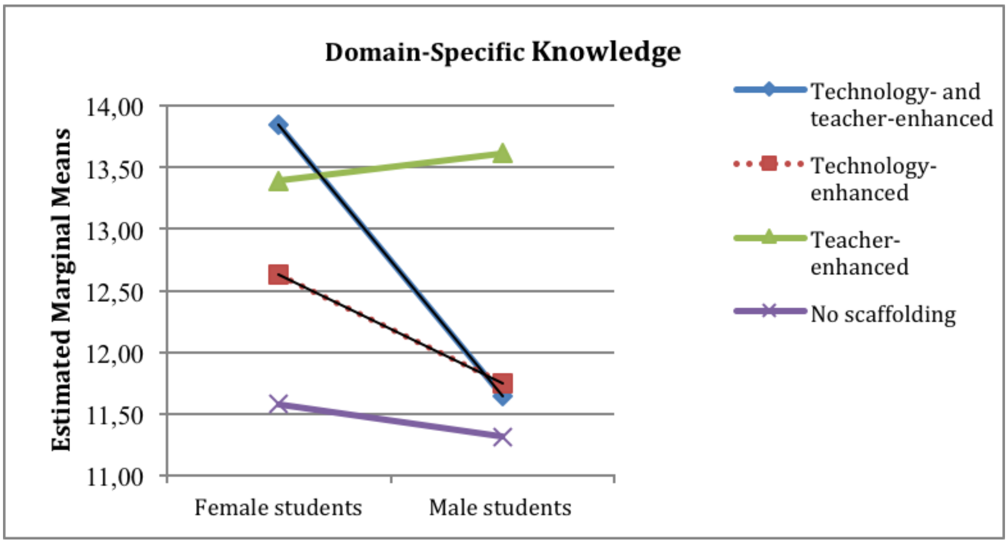

Figure 3. Line graph illustrating the interaction between gender and the scaffolding conditions with regard to post-test scores after adjustment for pre-test scores

Through pairwise comparison, with respect to girls, a significant mean difference (mean difference = 2.56, p = .021) between the combined scaffolding condition and the control condition is found. The other conditions do not significantly differ from each other. This means that the combined condition is most beneficial for girls. With respect to boys, however, it is the teacher-enhanced scaffolding condition which seem to be the most beneficial with a significant mean difference (mean difference = 2.05, p = .002) between the teacher-enhanced scaffolding condition and the control condition. No significant difference is found between the combined condition or the technology-enhanced scaffolding condition and the control condition.

Interaction with level of prior knowledge

Figure 4 shows the observed means for post-test scores, after adjustment for the pre-test, for the interaction between prior knowledge and scaffolding condition. There was no main effect for prior knowledge, but there was a significant interaction between scaffolding condition and prior knowledge. The interaction was further investigated using ANCOVA's to explore to what extent the scaffolding condition matters either for students with high or low prior knowledge.

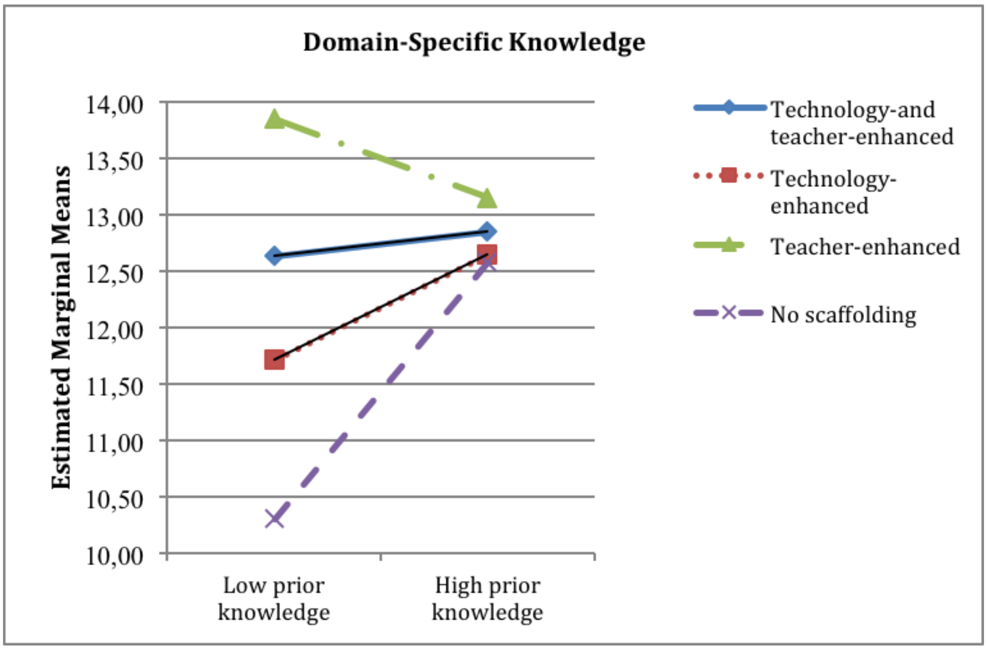

Figure 4. Line graph illustrating the interaction between prior knowledge level and the scaffolding conditions with regard to post-test scores after adjustment for pre-test scores

Regarding students with high prior knowledge, ANCOVA suggested that the four conditions do not significantly differ on the adjusted means ($F(3,155) = 0.37$, $p= .774$, partial $\eta^2 = .007$). Regarding students with low prior knowledge, however, ANCOVA confirms that the four conditions do significantly differ on the adjusted means ($F(3,138) = 9.49$, $p< .001$, partial $\eta^2 = .171$). Students with low prior knowledge significantly outperform in the condition with teacher-enhanced scaffolds (mean difference = 3.57, $p < .001$) or in combination with technology-enhanced scaffolds (mean difference = 3.49, $p < .001$) in comparison with the condition without scaffolds.

Based on these results, we can conclude that with regard to the acquisition of domain-specific knowledge especially teacher-enhanced scaffolding seems to affect learning outcomes, particularly for students with low prior knowledge. According to gender, boys benefit the most when provided with teacher-enhanced scaffolding, whereas girls perform the best teacher-enhanced scaffolds in combination with technology-enhanced scaffolds.

Students' metacognitive awareness in relation to IPS

Second, the effects of multiple modes of scaffolding on students' metacognitive awareness were explored. This metacognitive awareness was according to Schraw and Dennison (1994) split up in *knowledge about cognition* and *regulation of cognition*.

Knowledge about cognition

The scale *knowledge about cognition* aimed to measure students awareness of one's strengths and weaknesses during a web-based inquiry project and their knowledge about strategies and why and when to use those strategies. It was questioned if students' *knowledge about cognition* improved after a web-based project and more important if this improvement is determined by the way students' Information Problem Solving was scaffolded through embedded instruction. Students from the four conditions did not significantly differ from each other on the pre-test. After the intervention, however, all students reported a higher *knowledge of cognition* and an ANCOVA confirmed that conditions did significantly differ regarding the post-test adjusted means ($F(3,321) = 4.36$, $p = .005$, partial $\eta^2 = .039$).

Pairwise comparisons suggest that the condition with a combination of teacher-enhanced and technology-enhanced scaffolding significantly outperformed the control condition without scaffolds (mean difference = 0.17, $p = .006$).The differences between the other conditions were not significant.

Regulation of cognition

Finally, the scale *regulation of cognition* aimed to measure whether students could apply the IPS-strategies that were scaffolded in different ways during the web-based inquiry project. Students were asked to what extent they performed the subprocesses of IPS that facilitates self-regulated learning, i.e. planning, information management, comprehension monitoring, and evaluation. All students reported performing more regulation after the intervention than before. Particularly, the condition with combined scaffolds and the condition with technology-enhanced scaffolds realized a high learning gain.

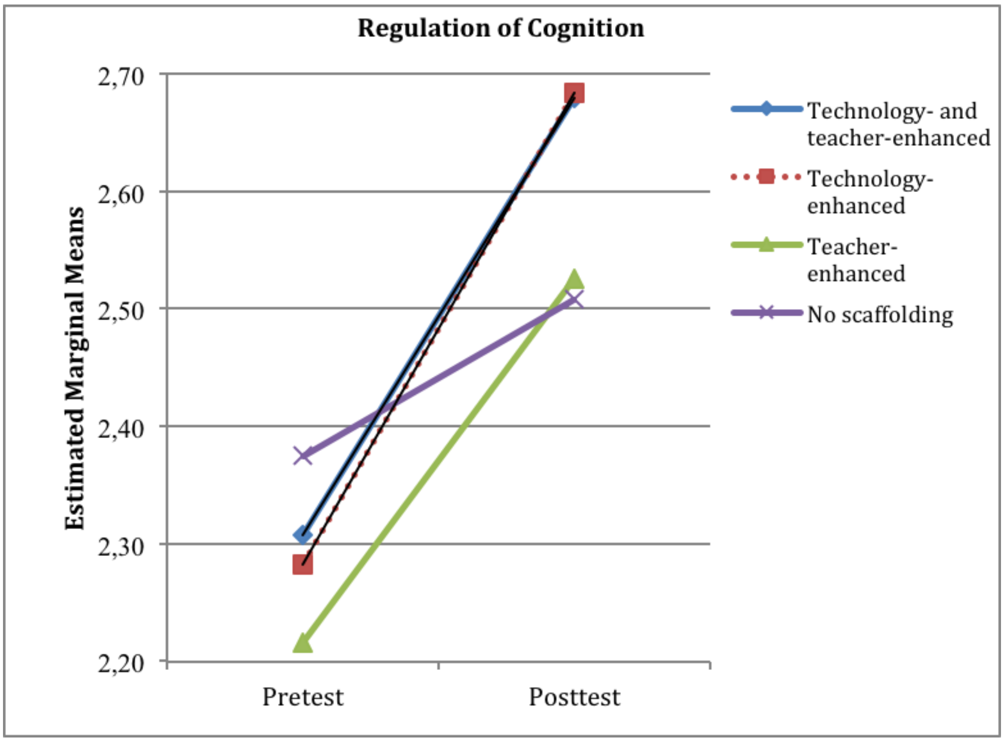

Figure 5
Line graph illustrating pre- and post-test descriptives for regulation about cognition

ANCOVA indicated that the four conditions did significantly differ on the post-test measure, after adjustment for the pre-test scores ($F(3,321) = 5.70$, $p = .001$). Pairwise comparisons showed that both the condition with technology-enhanced scaffolds (mean difference 0.22, $p = .004$) and the condition with teacher- and technology-enhanced scaffolds (mean difference 0.20, $p = .004$) significantly differ from the control condition. No significant differences were found between the other conditions. From these results we can conclude that with regard to improvement in IPS-skills technology-enhanced scaffolding seems to affect more transfer than teacher-enhanced scaffolding. No interaction effects were found according to gender and students' prior knowledge.

Discussion and conclusion

Despite the widespread recognition of the need to scaffold students during web-based inquiry learning, the understanding of how students' metacognitive awareness can be supported in authentic classroom settings is rather limited. Especially, more insight is needed in how to foster students' web-based information problem solving skills, a pivotal 21st century skill which is required in everyday life in and out of the classroom. The Internet brings up-to-date scientific findings in the reach of everyone, yet searching and finding relevant, credible, and scientifically substantiated information on the Internet is a challenging task. Consequently, an important question that arises is how to support the information problem solving skills of a variety of students. This question drove our research and practice. We implemented a web-based inquiry project with embedded instruction in real classroom settings.

During this project, students were faced with several information problems to be solved by means of evidence from the web. The purpose of this study was to investigate whether the presence of metacognitive and strategic scaffolds improved students' domain-specific knowledge and their metacognitive awareness of their IPS-processes. While most studies within the context of web-based inquiry learning focus on technology-enhanced scaffolding, this study also took into account the role of the teacher with respect to scaffolding IPS. Consequently, the effectiveness of technology-enhanced, teacher-enhanced scaffolding, and the combination of both forms of scaffolding, together with the way they interact with students' gender and prior knowledge were examined. The three experimental conditions (teacher-enhanced scaffolding, technology-enhanced scaffolding, and the combination of both modes) were compared with a control condition in a two-by-two factorial quasi-experimental design.

Our results indicate that learning by means of a web-based inquiry project with embedded scaffolding contributes to enhancing learners' domain-specific knowledge and to enhancing their metacognitive awareness. This conclusion is based on evidence to an overall increase in students' performances. However, the question is which scaffolding condition is most beneficial for a mix of students (i.e. boys and girls with different levels of prior knowledge) and regarding the learning objectives (i.e. knowledge acquisition and metacognitive awareness).

With regard to knowledge acquisition, teacher-enhanced scaffolding is found to be a determining factor. Students provided with teacher-enhanced scaffolds that facilitate the information problem solving skills and metacognitive processes, reach statistically significant higher knowledge performances scores compared to students in classes without teacher-enhanced scaffolding. Moreover, when we questioned to what extent the effectiveness of scaffolding is influenced by students' characteristics, a significant interaction was found between the scaffolding conditions and prior knowledge. Although students with high prior knowledge performed equally on the knowledge post-test irrespective of the way they were scaffolded, the performances of students with low prior knowledge significantly differed with regard to the scaffolding condition. Students with low prior knowledge performed significantly better in the condition with teacher-enhanced scaffolds or in combination with technology-enhanced scaffolds in comparison with the condition without teacher-enhanced scaffolds. As a consequence, human interactions with the teacher or human tutor may prove to be important especially for more disadvantaged students because the teacher can dynamically monitor the information processes and help them to overcome their lack of domain knowledge. On the other hand, it seems that more advantaged students are able to perform successfully regardless of the scaffolding condition.

These findings are consistent with previous research that stressed that students with insufficient prior knowledge can suffer from minimal guidance (Kirschner et al., 2006). Moreover, Kim and Hannafin (2011) have suggested that learners who lack adequate prior knowledge need a teacher or human tutor who can scaffold or model information problem solving.

Subsequently, with regard to gender, a marginally significant interaction was found with the scaffolding condition. A remarkable finding was the fact that whereas the combined condition was the most beneficial one for girls, it was not so for boys for whom the teacher-scaffolded condition was the most beneficial. Based on these results, the combination of both modes of scaffolding may produce for boys an "over-scripting effect" as conceptualized by Dillenbourg (2002). In this respect, the technology-enhanced scaffolds guided students IPS, but if the learner already has an internal script of how to fulfill the task, the performance of the learner might decrease (Stegmann, Mu, Gehlen, Baum, & Fischer, 2011). The finding that the combined condition was not effective for boys might be related with the fact that in other research (e.g. Large et al., 2002; Roy et al., 2003; Liu & Huang, 2008, Ford et al., 2001) boys were found to encounter less disorientation problems, they generally feel themselves able to find their way around effectively and they do feel more in control compared to girls.

Although teacher-enhanced scaffolding is found to be a determining factor regarding knowledge acquisition, with regard to metacognitive awareness, technology-enhanced scaffolding seem to be more beneficially. Our results indicate that by providing technology-enhanced scaffolds, students' metacognitive awareness improved. Consequently, providing prompts as part of an external script may support the internalization of the strategic knowledge so that learners can apply the acquired knowledge to self-prompt actions in similar situations (Wang et al., 2011). With regard to metacognitive awareness, only providing students with these fixed scaffolds is as effective as the combined condition. No significant interactions with students' characteristics were found. Providing students with teacher-enhanced scaffolds but without incorporation of the embedded prompts, however, ends in significantly lower results.

In conclusion, if we want adequately support a diversity of students during web-based inquiry learning, which is aiming at knowledge acquisition as well as at improving information problem skills, multiple modes of scaffolding are needed to take into account individual differences between students. In this respect, our results support the notion of multiple, distributed scaffolding (McNeill & Krajcik, 2009; Puntambekar & Kolodner, 2005; Tabak, 2004) as an approach to enhance students' information problem solving during web-based inquiry learning. Consequently, our study produced promising results which may be of value for educational practice. Multiple scaffolding gives teachers the opportunity to differentiate between students by gender and with different prior knowledge. Moreover, this study provided new insight in ways to improve learning environments and scaffolding in order to reduce gaps between learners.

Limitations and implications for future research

This study took place in real classrooms and is conducted on large scale -347 students from 18 secondary school classes were involved in this intervention. Research in authentic settings is advantageous because they are highly ecologically valid, however they have some drawbacks. Due to the intervention on large scale and in real context, the available time and facility to measure learning processes was limited. In this study, IPS skills and strategy use were only measured by means of self-report. Additional research is needed to get more insight in the strategies students use during information processes on the web to reach more accurate conclusions about interaction with and the effect of scaffolding during the learning process. Further research can make use of thinking aloud protocols (Azevedo et al., 2008), log file recording (Perry & Winne, 2006), and/or eye-movement methods (Nüssli, Jermann, Sangin, & Dillenbourg, 2009) in order to find out in more detail how students actually perform the metacognitive and strategic learning activities during web-based collaborative inquiry. Moreover, more research is needed to get insight in what really happens in the context of the classroom during the scaffolding process to deepen the questions: Who searches for help? Who needs help? Who used the support that is offered?

Also the second limitation is due to the authentic research context in which several Master's students acted as teachers in different classrooms. Because of the large scale, it was hard to keep the intervention parameters completely under control. Nevertheless, a number of actions were undertaken to ensure that the intervention took place as intended (described above). The real classroom teachers – without knowing to which condition they belong – were asked to observe the Master's students and fill out an evaluation form evaluating the overall web-based project, as well as the quality of the intervention of the Master's students. This form of manipulation check informed us on how the Master's students interacted in the classroom. A teacher who was involved in the condition without teacher-enhanced scaffolding reported for example that from her opinion the Master's students could provide more profound help. On the other hand, a teacher from the condition with combined scaffolding, mentioned that the pacing of the project was to slow due to interruptions during the process. Many Master's students indicated their role in the classroom as a hard one to realize. Secondary students often gave the impression that they did not need help, but once they started to interact with those students they realized they could make a difference. However, to get more insight in teachers' role and in student-teacher interactions further research with a focus of the process of scaffolding is needed.

A final limitation of this study is the fact that all the measurements were conducted on the individual level. In accordance with previous research ((Lazonder, 2005; Lazonder & Rouet, 2008) suggesting that student dyads are generally better to apply (information) problem solving strategies and yield higher learning outcomes comparing with students who work individually, the web-based inquiry project was performed through collaborative work. Yet, regarding the fact that collaboration might have an effect on the regulation of the search task but considering that not all dyads collaborate in the same way (Rummel & Spada, 2005) the collaboration processes need to be taken into account as a factor. Further research needs to be conducted to identify and examine student interactions during web-based collaborative inquiry.

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Appendix A

Exemplary test items

Knowledge items	What is the difference between weather and climate? What is the IPCC?
Explanation items	Which part of figure B is comparable with the glass on figure A. Thick the right answer and explain your answer. The sun The cosmos The atmosphere  Figure A  Figure B

Appendix B

Scoring Rubric for knowledge items

Grade / score	Response description
0	Students have no or incorrect and irrelevant ideas in the given context.
1	Students have some relevant and correct ideas but do not connect them in a given context. There are still incorrect and irrelevant ideas included in the answer.
2	The answer is correct, but rather isolated. Students still fail to connect the relevant ideas.
3	Scientific concepts are explained correct and coherent as a token of a systematic understanding.

Appendix C

Scoring Rubric for explanation items

Grade / score	Response description
0	Students have no or incorrect and irrelevant ideas in the given context.
1	Correct multiple choice answer, but without further explanation.
2	Correct multiple choice answer with further explanation, but rather isolated and still some incorrect and irrelevant ideas are included.
3	Students have correct and relevant ideas but do not fully elaborate links between them in the given context. They still fail to connect the relevant ideas.
4	Students recognize connections between scientific concepts and understand how they interact. They have a systematic understanding and apply this in their explanation and argumentation.

Appendix D

Exemplary items of the two components of the adapted version of the Metacognitive Awareness Inventory (Schraw & Dennison, 1994) and the associated Cronbach's alpha’s

Scale	Items
Knowledge of cognition Consisted of 17 items Pre-test (α = 0.845) Post-test (α = 0.849)	• When searching the Internet for information I tried to use a method that had worked well in the past. • When I finished searching the Internet, I knew how good I had solved the information problem. • I knew what information was most important to solve the information problem. • I was good at presenting the information I had found on the Internet. • While searching the Internet for information, I deliberately turned my attention to important information.
Regulation of cognition Consisted of 15 items Pre-test (α= 0.847) Post-test (α =0.844)	• While searching the Internet for information, I often asked myself if my strategy would result in a good answer for the information problem. • I compared information from different Websites before I solved the information problem. • I asked myself questions about the subject before I started searching for information on the Internet • I asked for help when I did not understand anything when searching for information on the Internet • Once I finished searching the Internet, I asked myself how well I had answered the information problem.

4 Promoting socially shared regulation during collaborative problem solving on the web: when scripting does not work

This chapter is based on:

Raes, A., Schellens, T., De Wever, B., & Benoit, D. (Second round of review). Promoting Socially Shared Regulation during Collaborative Problem Solving on the Web: When scripting does not work. *Metacognition & Learning.*

Chapter 4
Promoting socially shared regulation during collaborative problem solving on the web: when scripting does not work

Abstract

Opportunities for collaborative work can support the process of information problem solving, including negotiating meaning, reconciling diverse sources and using valid, credible evidence, although this is not a straightforward or guaranteed outcome of collaborative work. Strong regulation ability is necessary for successful open-ended learning environments and web-based learning specifically. In the light of these issues, the present study was intended to investigate the regulatory processes that come into play when individual learners work collaboratively in solving information problems on the web and if these can be supported by providing students with a collaboration script. The web-based project was implemented in 12 secondary school classes involving 202 students working in pairs. Six classes were provided with a collaboration script embedded in the learning environment, while the other six classes acted as the control group. Although it was hypothesized that students in the script condition would yield higher socially shared regulation than students in the control condition without collaboration script, based on quantitative as well as qualitative analyses no significant improvement in socially shared regulation was found that could be attributed to the classroom script intervention. Yet it was found that shared regulation leads to better knowledge co-construction. Moreover, this study confirms that the overall implementation improved students' metacognitive awareness, however, no significant value was added by the collaboration script. Results are discussed concerning their theoretical relevance and practical implications for collaborative IPS on the web in face-to-face classroom settings.

Introduction

Whereas problem solving as defined for the Program for International Student Assessment (PISA) 2012 (OECD, 2010) relates to individuals working alone on resolving problem situations, as regards the preparation of PISA 2015 the aspect of collaboration is clearly emphasized (OECD, 2013). This indicates that collaborative problem solving (CPS) is seen as a critical and necessary skill across educational settings and in the workforce. Students emerging from schools into the workforce and public life are expected to have collaborative problem-solving skills as well as the ability to engage in collaboration using appropriate technology. Moreover, being able to regulate strategically one's own learning and that of others is a vital twenty-first century skill (Järvelä et al., 2014).

This shift from individual to collaborative problem solving is not only salient in educational settings and in the workforce, but has also recently been described in research literature (Chiu & Kuo, 2009; Greene & Azevedo, 2010; Jarvela & Hadwin, 2013; Järvelä et al., 2014). Collaborative problem solving is an inherently complex mechanism since it incorporates the components of cognition and regulation found in individual problem solving, in addition to the components of collaboration (Azevedo, 2014). This means these issues have become even more complex in the case of socially regulated learning, as exemplified by emerging conceptions of self-regulation, co-regulation, and socially shared regulation of learning (Jarvela & Hadwin, 2013), and metacognition and social metacognition (Chiu & Kuo, 2009). When learners work together they not only benefit from incorporation of information from multiple sources of knowledge, perspectives, and experiences (Lazonder, 2005; OECD, 2013), but also from social metacognition or shared regulation; since metacognitive responsibilities can be distributed, the visibility of metacognition is increased and individual cognition improves (Chiu & Kuo, 2009). However, students working together must also address several difficulties and cognitive, motivational, and socioemotional challenges may emerge; for example, communication challenges, status effects, and emotional differences (Barron, 2003; Hoadley, 2004; Lajoie & Lu, 2012). Good collaboration moreover implies balanced and equal participation in which knowledge is co-constructed and all members contribute different pieces of information or build upon each other's explanations to co-create a complete solution (Sampson & Clark, 2011). In this respect, earlier research recognized the need to know how small groups can be supported to counter and eliminate imbalances and how greater student interaction, socially shared regulation and social metacognition can be fostered.

Previous research stresses that support can be presented as an instruction that is given before (e.g. providing the RIDE rules consisting of the principles Respect, Intelligent collaboration, Deciding Together, and Encouragement (see Saab, Van Joolingen, & Van Hout-Wolters, 2007, 2012) or during interaction with the learning environment. A way to provide support during collaboration is providing students with a collaboration script to facilitate social, cognitive and metacognitive processes of collaborative learning by shaping the way learners interact with each other (Kobbe et al., 2007). According to Fischer, Kollar, Stegmann, and Wecker (2013), when speaking about scripts, we need to differentiate between internal and external scripts which are conceived as distinct but largely parallel in structure. An external (collaboration) script is regarded as a scaffold that may induce a functional configuration of an internal script which enables learners to engage in computer-supported collaborative learning (CSCL) practice at a level beyond their ability without an external script (Fischer et al., 2013). Several empirical studies on the effects of external collaboration scripts on CSCL practices showed that these scripts can improve CSCL discourse and (argumentative) knowledge construction (Kollar et al., 2007; Rummel & Spada, 2005; Schoonenboom, 2008; Weinberger, Stegmann, & Fischer, 2010). However, research examining the effects of a collaboration script on regulatory processes during collaborative problem solving on the web is inadequate and most scripting studies are conducted in a lab or in an asynchronous, distance setting (e.g. Kahrimanis et al., 2009). Additionally, it needs to be noted that regulation in general is a neglected area in computer-supported collaborative learning research and that there is relatively little research about how groups can be supported to engage in and productively regulate collaborative processes (Azevedo, 2014; Jarvela & Hadwin, 2013; Järvelä et al., 2014).

This paper fills these gaps and presents a study within the context of a web-based inquiry project designed to improve students' knowledge integration in science and to improve their metacognition in daily classroom practices (see Raes, Schellens, De Wever, &. Vanderhoven, 2012; Raes, Schellens, & De Wever, 2014 for an overview of the project objectives and design). Based on the three-level model for designing activities to improve students' metacognition proposed by Chiu and Kuo (2009), the implementation can be categorized as a level 3 social training implementation since students are asked to solve challenging problems in dyads and therefore they need to apply both communication and metacognitive skills. Students are supported by a technology-enhanced environment which prompts the acquisition and activation of regulatory processes. Moreover, this study is designed to test the implementation of a collaboration script by assigning roles to students and attempting to foster specific social metacognitive strategies by means of a quasi-experimental design.

As depicted in Figure 1, the first research question investigated whether the collaboration script implemented in this study can positively affect students' socially shared regulation during collaborative problem-solving activities. Since the script distributed the cognitive and metacognitive responsibilities and was intended to stimulate the reciprocal process of questioning and prompting in peer interactions, it was hypothesized that students in the script condition would yield higher socially shared regulation than students in the control condition without a collaboration script. Second, in line with the strong consensus that successful learners self-regulate their learning by using a repertoire of strategies while completing tasks, it was hypothesized that better shared regulation would lead to better co-constructed knowledge. Third, it was questioned if the overall implementation, and the collaboration script implementation more particularly, could improve students' individual metacognitive skills and if the intervention helped the students to learn more strategies and perform better in terms of argumentative writing.

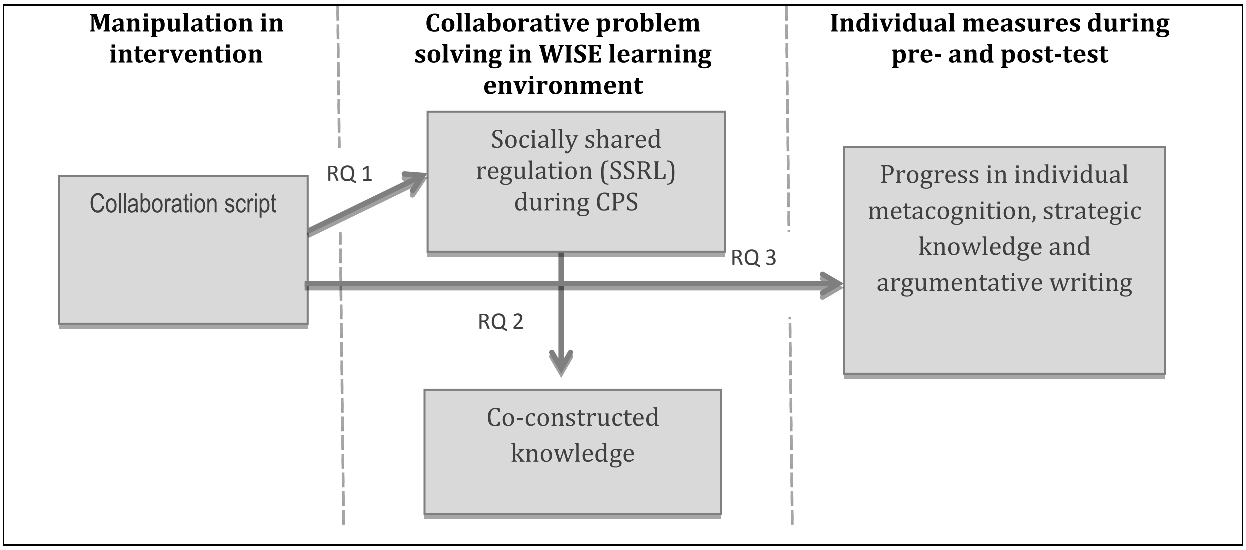

Figure 1. Model depicting the expected relation between the (manipulation within the) intervention, socially shared regulation, co-constructed knowledge and progress in individual metacognition, strategic knowledge and argumentative writing

Before the context and methodology are explained in detail, some of the main theoretical concepts will be elaborated.

Information problem solving on the web

Information and computer technologies and more specifically the World Wide Web have received increased attention in education because of their potential to support new forms of (collaborative) inquiry (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). When the World Wide Web is used as a source within inquiry learning it supports the development of higher-order skills such as critical thinking and problem solving (Linn, Clark, & Slotta, 2003). However, although learning in such dynamic environments is much more engaging, it is also much more challenging (Kuiper, Volman, & Terwel, 2009; Wiley et al., 2009).

The World Wide Web is an extensive source of information and strong self-regulation ability and metacognitive awareness are necessary for successful web-based learning (Brand-Gruwel, Wopereis, & Walraven, 2009). However, contemporary cognitive and educational research has shown that most students have difficulty regulating their learning as well as performing metacognitive activities spontaneously (Azevedo & Cromley, 2004; Lazonder & Rouet, 2008) and even good learners experience trouble regulating learning in a hypermedia environment (Lajoie & Azevedo, 2006) and seem to have a fragile understanding of how to judge the quality of information (Wiley et al., 2009). Understanding how students engage in the processes of search, selection, evaluation, comparison, and integration of ideas from multiple sources of information has become an increasingly important area of research in library and information sciences (Blummer & Kenton, 2014; Eisenberg & Berkowitz, 1990) and in learning and educational sciences (Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012.; Walraven, Brand-Gruwel, & Boshuizen, 2012; Wecker, Kohnlet, & Fischer, 2007). Goldman et al. (2012) for example used think-aloud protocol methodology for better understanding of the processing that learners engaged in during a web-based inquiry task on the causes of volcanic eruption: 10 better learners were contrasted with 11 poorer learners and findings suggested that multiple-source comprehension is a dynamic process that involves interplay among sense-making, monitoring, and evaluation processes, all of which promote strategic reading and better learning outcomes. This is consistent with earlier research indicating that the cognitive components of information problem solving include understanding and representing the problem content, applying problem solving strategies, and applying self-regulation and metacognitive processes to monitor progress toward the goal (Azevedo & Witherspoon, 2009; Funke, 2010).

Several research studies in the individual self-regulation field examined factors that promote greater self-regulation in learning from hypermedia and found that overall the results suggest that self-regulation can be improved by external supports using human tutors or technology-enhanced scaffolding (Schraw, 2007). Yet, unlike other studies, that by Graesser et al. (2007), who examined the impact of the SEEK web tutor on college students' critical stance and learning while exploring web pages on science, did not find significant improvements that could be attributed to the intervention. One of our own previous studies (Raes et al., 2012) questioned how to foster students' web-based information problem-solving skills in real classroom settings and investigated more particularly whether the presence of metacognitive and strategic scaffolds improved students' domain-specific knowledge and their metacognitive awareness of their IPS processes. Results indicated that technology-enhanced scaffolding that prompted students to perform the different steps in the external Big6 script (Eisenberg & Berkowitz, 1990) improved students' metacognitive awareness. These results supported the possible internalization of strategic knowledge so that learners can apply the acquired knowledge to self-prompt actions in similar situations (Wang, Kollar, Stegmann, & Fischer, 2011).

Collaborative problem solving on the web

Collaborative problem solving has distinct advantages over individual problem solving because it allows for the incorporation of information from multiple sources of knowledge, perspectives, and experiences (OECD, 2013; Lazonder, 2005). However, engaging other group members in a collaborative task requires additional cognitive, metacognitive and social skills to allow shared understanding and knowledge, to create an appropriate team organization, and to perform coordinated actions to solve the problem (OECD, 2013). In collaborative learning research, regulatory processes have usually been considered from a cognitive perspective and, thus, the definition has been linked to cognitive processes involved in for example knowledge co-construction (Hmelo-Silver & Barrows, 2008). However, Järvelä and Hadwin (2013) indicate that conceptions of learning need to extend cognitive processes and outcomes. When individuals work collaboratively, three types of regulated learning come into play and contribute to collaborative success. These three types are: self-regulated learning whereby each group member takes responsibility for regulating his or her learning, co-regulated learning whereby each member supports fellow group members to regulate their learning, and shared regulation whereby the group comes together collectively to regulate learning processes in a synchronized and productive manner. This means that shared regulation refers to the processes by which group members regulate their collaborative activity (Järvelä et al., 2014), orchestrated in the production of a co-constructed or shared outcome (Hadwin, Järvelä, & Miller, 2011). Azevedo (2014) has recently raised theoretical, conceptual, methodological, and instructional issues that should guide future research in the area of metacognition and learning. One of his concerns is that there is relatively little research about how groups and individuals in those groups engage, sustain, support, and productively regulate collaborative social processes. In this respect, this study is part of the attempt to meet this gap.

Method

Context, design, participants and procedure

This study is embedded in a larger design-based research project extending over five years and meant to contribute to three outcomes related to science learning: knowledge acquisition, problem-solving skills and motivation for science. After a pilot study (see Raes et al., 2014), a first iteration (Raes et al., 2012) as described above questioned how to foster students' web-based information problem-solving skills in real classroom settings. A limitation of this study was that all the measurements were conducted on the individual level, although the web-based inquiry project was performed through collaborative work. Given that peer learners can also be considered as a source of supporting regulation during inquiry (Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003) but that not all dyads collaborate in the same way (Mullins, Rummel, & Spada, 2011), the collaboration processes needed to be taken into account in subsequent studies. Consequently, this particular study focuses on the regulatory processes that come into play when individual learners work collaboratively to solve information problems on the web and questions if these can be supported by providing students with a collaboration script.

The effects of web-based collaborative problem solving and more specifically of the integration of the collaboration script on students' regulatory processes during IPS on the web were investigated through a quasi-experimental field study. In total, 207 students from 12 different secondary school classes (grades 9 and 10) were involved. Six classes were provided with the collaboration script embedded in the curriculum project (script condition, N = 99 students) and six classes were not provided with this collaboration script (no script condition, N = 108 students). The average age of the students was 16 years (SD = 0.67); 38% of the group were girls and 62% boys. The classes came from six secondary schools in Flanders and a group of eight science teachers were involved in the research project who agreed to dedicate four class periods (50 minutes each) to implement the web-based inquiry project. During the first session, students completed an individual pre-test and were introduced to the Web-based Inquiry Science Environment (hereafter referred to as WISE). Subsequently, they started working in dyads on the first introductory activity of the WISE project. Students worked in the same small groups during the whole intervention. After completing the project, all students completed an individual post-test. The pre- or post-test was missing for five students absent from this particular session and they were excluded from the dataset. Therefore, data from 202 students remained for analysis.

To enable a large-scale implementation in authentic classrooms this research project was set up in the context of a collaboration between science teachers in secondary education and a Master's degree program in educational studies. Each teacher was assisted by two Master's students in educational sciences to conduct and support the implementation of the project and the data collection. For these Master's students, the assignment was a formal part of the educational technology course at Ghent University. All these students received thorough training and were fully prepared to implement the intervention following a strict protocol and according to a set of instructional principles.

Collaborative scenario and web-based setting

In this study we focus on the collaborative activities that arise in web-based collaborative inquiry learning. Students used one computer per dyad and were supposed to explore the topic of global warming and climate change by means of WISE. WISE is a promising theory-driven and research-based learning environment developed by the Technology-Enhanced Learning in Science (TELS) Research Community (Slotta & Linn, 2009).

The WISE authoring environment was used to create a curriculum project that was closely tied to the regular curriculum and was integrated in educational practice (see Raes et al. (2014) for an overview of this inquiry project). To maintain the construction of knowledge on the one hand through the knowledge integration approach (Linn & Eylon, 2011), all the inquiry activities followed the instructional pattern, starting with eliciting the ideas that students already held. Then students got the opportunity to add new ideas and distinguish among ideas by searching and critiquing web-based evidence, exploring simulations or interactive graphs, and discussing them with peers. In the end, students needed to reflect on these ideas to integrate them in their repertoire.

To support the strategic processes of searching and critiquing web-based evidence on the other hand, in the light of previous research (Raes et al., 2012) students were provided with the Big6, a six-stage model designed to help learners solve problems or make decisions by using information (Eisenberg & Berkowitz, 1990). As depicted in Table 1, based on the results of Raes et al. (2012), the Big6 model was embedded in the inquiry project by means of technology-enhanced scaffolding, meaning that students got hints and were prompted throughout the project to perform the steps, though these prompts gradually faded out throughout the project.

Table 1

The Big6 script and the corresponding hints and prompts were embedded in the learning environment

IPS skill decomposition	Corresponding scaffolds
#1 Task Definition	
1.1 Define the information problem 1.2 Identify information needed	- What does your teacher want you to do? - Restate/rewrite the assignment in your own words - Activate prior knowledge - What information do you need to include in your answer?
#2 Information Seeking Strategies	
2.1 Determine all possible sources 2.2 Select the best sources	- Consider the possible sources of information that will help you answer the question - Think about relevant keywords and specify search terms - Evaluate/judge the list of sources
#3 Location & Access 3.1 Locate sources (intellectually and physically) 3.2 Find information within sources	- Figure out where you will find these sources, read global information - Try to find relevant and useful sources Look at the title, index and date. Scan the information using your keywords from step 2 - Try to find reliable sources: what is the aim of the website? Who is the writer of the website? Can you find data that confirm the information?
#4 Use of Information 4.1 Engage 4.2 Extract relevant information	- Read, view, or listen to the sources you located during step 3 - Compare information from multiple sources - Take notes to answer the questions you formulated in the first step - Try to paraphrase or summarize ideas instead of just copying information word-for-word from your sources - Be sure to give credit to your sources
#5 Synthesis	
5.1 Organize from multiple sources 5.2 Present the information	- Structure relevant information from multiple sources - Outline your answer - Did you cite the source at point of use in your answer (using a footnote or parenthetical reference)?
#6 Evaluation	
6.1 Product 6.2 Process	- Does your answer meet the information problem / question asked at the beginning of the inquiry? - Did you answer it efficiently? How can you improve the process?

Implementation of the collaboration script

Based on the results of the previous study, this study was designed to promote beneficial collaborative learning and shared regulation during IPS by implementing a collaboration script. The collaboration script is based on the framework of Kobbe et al. (2007), who differentiate between script components, that is, the elements a given script is composed of (participants, roles, activities, resources, groups), and script mechanisms, that is, functions regulating the relationships between the components (task distribution, group formation, and sequencing). The script in this study particularly focused on the script component of role assignment and the script mechanisms of task distribution and sequencing. As shown in Figure 2 the collaboration script was implemented in the WISE project as display pages which instructed students which role to perform and when to switch roles.

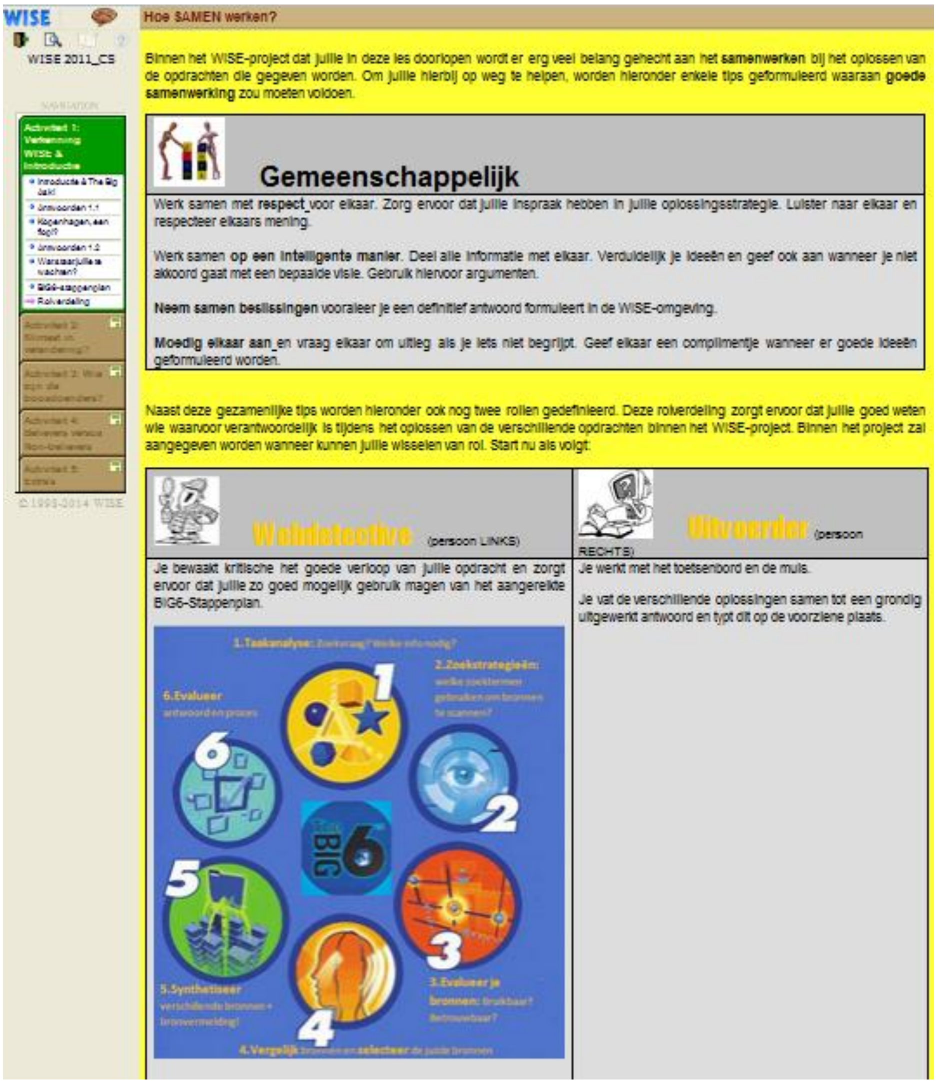

Figure 2. Display page with collaboration script instructions here first shown in the introductory activity

The collaboration script was intended to prevent uneven participation by introducing the RIDE rules (in the upper box) as joint accountability and assigning students a roles with individual responsibility (web detective vs. executer) for completing the task. Students were prompted to switch roles at the beginning of each new activity. Excluding the introductory activity, there were four main activities, so students played the same role twice. The executer was responsible for conducting the keyboard and mouse to search the web and type the answers. The web detective on the other hand was asked to be the critical friend and was responsible for metacognitive evaluation regarding the performance of the Big6 strategies (previously described), including for example activating prior knowledge, judging the sources and citing the sources. In the no-script condition the RIDE rules were not given and no student roles and task division were suggested; it was up to the students to decide how to divide the tasks.

Mixed methods paradigm

Design-based research methodology is a well-used research approach in the learning sciences (Barab & Squire, 2004; Brown, 1992; The Design-Based Research Collective, 2003) and relies on multiple sources of evidence, both quantitative and qualitative, which are triangulated to make use of the strengths of both research paradigms (Johnson & Onwuegbuzie, 2004). Several authors (e.g. Creswell, 2008; Denzin, 2008; Greene, 2008; Trifonas, 2009) suggest the power of integrating different approaches from a mixed methods perspective in answering research questions and in strengthening the inferences in terms of both processes of analysis and outcomes of analysis. Moreover, methodological pluralism enables errors in single approaches to be identified and rectified, and new modes of thinking to emerge when paradoxes between two individual data sources are found (Johnson, Onwuegbuzie, & Turner, 2007). Although this study largely represents the results of quantitative research, whereby quantifiable data regarding a large number of participants were collected and statistically analyzed by means of multilevel modeling, qualitative research is also explored and employed whereby data are collected from a subgroup and consist of participants' words and interactions (Creswell, 2008).

Multilevel modeling as quantitative analysis

Quantitative data were collected from all respondents regarding students' self-reported shared-regulation, students' collaborative knowledge construction, and students' individual problem-solving skills and metacognitive awareness.

To solve the first research question, as depicted in Table 2, all students of all classes were individually asked in the post-test to self-evaluate their shared performance of the Big6 strategies from the "We" perspective on a five-point Likert scale.

Table 2

Items corresponding to each of the Big6 strategies used to evaluate students' shared regulation during IPS

1) Identifying information research goals: *We analyzed the task / problem thoroughly before searching for information.*
2) Seeking and selecting the best sources: *We discussed possible quests/keywords before we started our search.*
3) Finding information within the sources: *We examined/discussed whether the found information was useful and reliable.*
4) Using and collecting relevant, credible information: *We compared several sources and we gave each other reasons why a particular source was useful or not.*
5) Synthesizing and presenting information from multiple sources: *We combined – if necessary - several good sources to improve our answer.*
6) Product and process evaluation: *We evaluated ourselves after formulating our answer.*

Yet, since students individually assessed their group functioning and students came from existing classes, the problem under investigation has a clear hierarchical structure. This implies that individual observations are generally not fully independent because of the common history and experiences individuals share by being part of the same group (De Wever, Van Keer, Schellens, & Valcke, 2007; Hox, 1994). In this respect, multilevel modeling has been used to discover the degree of similarity of students working together in pairs and of pairs coming from the same class. Six three-level models (i.e. individuals within groups within classes) were built to model the shared regulation regarding the Big6 strategies. The software MLwiN 2.23 for multilevel analysis was used to analyze the hierarchical data and the multilevel models were estimated with the iterative generalized least squares (IGLS) procedure in order to build and compare them.

To answer the second research question regarding the relation between shared regulation and co-constructed knowledge a group performance score was needed. During the WISE project the groups were required to complete the inquiry activities collaboratively. All teamwork was stored in the database which was coded according to an adapted version of the knowledge integration rubric that rewards both accurate and connected ideas (see Raes et al., 2014) and this resulted in a group performance score for each group (min. 0 – max. 20). All students' teamwork was coded by two independent raters who received training in applying the rubrics. Krippendorff's alpha reliability statistics were calculated to judge the inter-rater reliability of the coded variables (Hayes & Krippendorff, 2007) and these are shown in Appendix A. The reliability rate was satisfactory since all the Krippendorff's alphas (Kalphas) were 0.67 or higher and a Kalpha of 0.80 is often seen as the norm for good reliability, with a minimum of 0.60. Again, multilevel modeling – now with group as lowest level – was used to predict to what extent the shared regulation of the Big6 would lead to better co-constructed knowledge.

With the third research question we wanted to investigate whether social metacognition supported by the learning environment and the collaboration script particularly could facilitate improvement of individual metacognition, strategy knowledge and performance, and argumentative writing. To measure this, students in pre-test and post-test were individually faced with an unfamiliar information problem they needed to solve individually, specifically a scientific controversy (i.e. "Mobile phone radiation: harmful or nonsense?" or "Fewer pimples! Just by changing what you eat! Fact or myth?"). Students were required to take up a particular position that they needed to justify with appropriate evidence from the web to support their claim (see Appendix B for the task as presented to the students). To ensure that any differential effects were not the result of varying task difficulty, the two scientific controversies were counterbalanced. As depicted in Appendix B, in the first subsection of the task, students' strategic knowledge was measured by asking them to describe as clearly as possible how they performed the task and what they kept in mind during this process. In the second subsection, students' argumentative writing performance was measured by asking them to formulate their claim and justify it with arguments from the web. Finally, in a third subsection after the IPS task, students' metacognitive awareness while performing the task was measured by means of an adapted version of the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) which has been validated and successfully used in previous research (Raes et al., 2012). This self-report inventory is based on the two-component view of metacognition, that is, knowledge of cognition and regulation of cognition (see Appendix B for sample items of the two components of the MAI). Additionally, the scoring rubrics used to code students' descriptions of their performance of the IPS task and to code students' positions in the scientific debates can be found in Appendix C.

The Kalpha estimations based on the coding of the two independent raters are also shown in Appendix A and we can conclude that the Kalpha values regarding the coded variables are, except for two, between 0.62 and 0.96, which indicates good inter-rater reliability. Regarding the coding of Step6_pre-test and Step2_post-test the Kalphas are too low at 0.16 and 0.24 respectively. We investigated these variables in detail and noted that the low Kalphas result from the fact that there are very few answers coded as category 2. Since the percentage agreements for both variables are 98% and 87.4% respectively, which is satisfactory, the low Kalphas are attributed to the strict chance corrections for the low counts of category 2 in the data.

Since we were especially interested in whether students made progress, new variables were devised for the three individual sub-measurements and these progress data were analyzed by means of three-level modeling. Since strategic knowledge and argumentative writing scores were ordered variables instead of continuous ones like the MAI results, ordered logit was used to analyze these variables (Chiu, 2008).

Multiple case studies as qualitative analysis

Qualitative data were collected from two randomly selected dyads per class, yet the qualitative research described in this study was only conducted on a sample of four dyads. This sample of four dyads was selected sequentially on the basis of group performance scores

(Cohen, Manion, & Morrison, 2011). The purpose of this sampling was not to make generalizations, but to present them as multiple case studies in contrasting settings to gain insight first into how groups in the script condition dealt with the collaboration script and how students without scripts shaped their collaboration regarding task division and role play, and second into the relation between the group performance of students and the performance of the Big6 information processing strategies.

Students' interactions were observed and audiotaped by the two Master's students in educational sciences who assisted with the implementation of the project; each student followed one dyad. As an alternative to transcription, LeCompte and Preissle (1993) advised setting out the main outlines of the phenomena under investigation and assembling blocks of data, putting them together to make a coherent whole. To operationalize this, a rating scheme based on that of Meier, Spada, and Rummel (2007) was used in which the observers could rate the quality of collaboration and regulation for every observed session. Every given score needed to be justified by observable behavior and excerpts from the audio recording. Although the rating scheme consisted of more than shared information processing, task division, and role taking, we will focus on these aspects in line with the scope of the collaboration script.

It has been indicated that with qualitative data the analysis is almost inevitably interpretative, and hence it is not a completely accurate representation but more of a reflexive, reactive interaction between the researcher and the decontextualized data that are already interpretations of a social encounter (Cohen et al., 2011, p. 554). In practical terms it means that the researcher may be selective in his/her focus, or the research may be influenced by the subjective features of the researcher (Vanderhoven, Raes, & Schellens, 2015). In line with Shenton (2004) this has been countered in this study by first requiring two independent raters to rate all the data, conduct random sampling for observation and subsequently select the cases for in-depth qualitative research based on a quantitative measure and second by adopting theory-driven and previously validated rubrics and quality criteria and by organizing two debriefing sessions between the coders and the main research steering group (that is, the first two authors).

Results

Quantitative analyses

RQ 1: Effect of collaboration script on students' socially shared regulation

Since the script distributed cognitive and metacognitive responsibilities and was designed to stimulate the reciprocal process of questioning and prompting in peer interactions, it was hypothesized that students in the script condition would yield higher socially shared regulation than students in the control condition without collaboration script. A three-level model was conducted for each of the six self-reported performances of the Big6 strategies and the results are presented in Table 3.

From the fixed part of the unconditional null model, we can state that across all students the average (*SE*) reported shared regulation is between 2.95 (0.11) and 3.43 (0.08) on a five-point Likert scale (= intercept β_0) which indicated that students on average "roughly agree" that they collaboratively performed the Big6 strategies during the web-based inquiry project. Moreover, the null model partitions the variance into between classes, within class - between groups, and within group - between students components. Given the random part results, we can state that regarding all the Big6 strategies most of the variance is situated at the student level (intra-class correlation or ICC between 63.1% and 83.6%) and no significant variance is situated at the class level (ICC between 1% and 7.1%). The variance at the group level varies between 11.1% and 29.7%, but only regarding three of the Big6 strategies is this group-level variance significant, which means that the degree of similarity in reports about the shared performance of a certain strategy varies among the strategies. Regarding the other three Big6 strategies, unexpectedly there is no significant degree of similarity on group level since students were asked to assess their regulation in the group from a "We" perspective.

The design effects (DE) regarding level 3 class and level 2 group (e.g. for Big6_1 DE = 1+((106/13)-1)*(0.03)= 1.21) and regarding level 2 Group and level 1 Student (e.g. for Big6_1 DE = 1+((214/106)-1)*(.25)= 1.25) are all lower than 2.0 and suggest we should exclude the levels from the model (Peugh, 2010). However, we decided to keep the multilevel structure because there was significant group variance regarding three of the six strategies and it gives interesting information about how students vary among groups and classes.

In the next step the variable condition was added to the model with no script as reference category to answer the first research question. However, given the results shown in Table 3, the hypothesis that students in the script condition would yield higher socially shared regulation than students in the control condition without collaboration script could not be confirmed. Only regarding Big6_strategy4 a marginally significant effect could be found for the script condition ($\chi^2 = 2.78$, $df = 1$, $p = 0.09$). Moreover, a nested hypothesis test (chi-square goodness of fit test) checked whether the added variable was significant, but as indicated in the table this was not the case.

Table 3

Multilevel parameter estimates for the three-level analyses of students' reported information processing

	Big6_1		Big6_2		Big6_3		Big6_4		Big6_5		Big6_6	
	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model
Fixed part												
Intercept β_0	3.32	3.33	2.95	2.86	3.045	2.96	2.99	2.86	3.43	3.31	3.29	3.32
	(0.09)	(0.13)	(0.11)	(0.16)	(0.10)	(0.14)	(0.04)	(0.11)	(0.08)	(0.11)	(0.10)	(0.14)
Collaboration		-0.01		0.16		0.17		0.26		0.22		-0.05
Script β_1		(0.18)		(0.22)		(0.19)		(0.15)		(0.15)		(0.20)
Random part												
(L3) Class	0.03	0.03	0.08	0.07	0.07	0.06	0.02	0.01	0.01	0.00	0.02	0.02
variance	(0.04)	(0.04)	(0.07)	(0.06)	(0.05)	(0.05)	(0.04)	(0.03)	(0.03)	(0.00)	(0.05)	(0.05)
(L2) Group	0.25*	0.25*	0.33*	0.33*	0.11	0.11	0.14	0.14	0.17	0.16	0.37	0.37
variance	(0.09)	(0.09)	(0.11)	(0.11)	(0.09)	(0.09)	(0.10)	(0.10)	(0.11)	(0.10)	(0.13)*	(0.13)*
(L1) Student	0.63*	0.63*	0.70*	0.67*	0.81*	0.81*	0.86*	0.86*	0.92*	0.93*	0.86*	0.86*
variance	(0.09)	(0.09)	(0.10)	(0.10)	(0.11)	(0.11)	(0.12)	(0.12)	(0.13)	(0.13)	(0.12)	(0.12)
Model fit												
-2*log likelihood	575.44	575.43	609.24	608.72	596.55	595.86	608.97	606.47	624.02	621.97	644.56	644.49
χ^2 (df = 1)		0.01		0.52		0.69		2.5		2.05		0.07
p		0.92		0.47		0.41		0.11		0.15		0.79
Tot variance	0.91		1.11		.99		1.02		1.1		1.25	
ICC Class	3,4%		7.2%		7.1%		1.9%		1%		1.6%	
ICC Group	27.4%*		29.7%*		11.1%		13.7%		15.4%		29.6%*	
ICC Student	69.2%*		63.1%*		81.8%*		84.3%*		83.6%*		68.8%*	

Note. Standard errors are in parentheses. * indicates $p < 0.05$

RQ 2: Effect of shared regulation on co-constructed knowledge

Although from the previous research question it is known that the collaboration script did not lead to higher shared regulation (on which we will elaborate in the qualitative analysis section as well as the discussion section), it was still interesting to know if better shared regulation would lead to better co-constructed knowledge. To investigate this hypothesis, a two-level model was built with students' group performance out of 20 as dependent variable. The self-reported performances of the Big6 strategies (see Table 2) were added as independent variables. Results shown in Table 4 reveal that only Big6_1, that is, thoroughly analyzing the task and problem before searching for information, significantly predicts a better group performance (χ^2 = 14.08, df = 1, p < 0.001).

Table 4

Multilevel parameter estimates for the two-level analyses of students' group performances (0-20)

Parameter	Null Model	Big6 Model
Fixed part		
Intercept β_0	12.47* (0.66)	3.04* (0.09)
Bi6_1 Identifying information research goals		0.71* (0.12)
Bi6_2 Seeking and selecting the best sources		-0.22 (0.18)
Bi6_3 Finding information within the sources		0.19 (0.19)
Bi6_4 Using and collecting relevant, credible information		-0.03 (0.19)
Bi6_5 Synthesizing and presenting information from multiple sources		-0.18 (0.17)
Bi6_6 Product and process evaluation		0.11 (0.17)
Random part		
Level 2-Class variance	5.32 (2.20)	4.47 (1.90)
Level 1-Group variance	4.34 (0.43)	4.05 (0.40)
Model fit		
-2*log likelihood (Deviance)	975.42	944.52
χ^2		30.9
df		6
p		< 0.001

Note. Standard errors are in parentheses. * indicates p < 0.05

RQ 3: Effect of web-based collaborative problem solving and the collaboration script on students' progress in information problem solving skills

Third, it was questioned if the overall implementation - and the collaboration script implementation more particularly - improved students' individual metacognitive skills and helped them to learn more strategies and perform better in terms of argumentative writing. To answer these research questions the progress in individual performances were analyzed.

Progress in metacognitive awareness

Two paired sample t-tests conducted on a single level revealed significant improvements from pre- to post-test regarding both knowledge of cognition ($t(201) = -6.19$, $p < 0.001$; ES = 0.13) and regulation of cognition ($t(201) = -6.30$, $p < 0.001$, ES = 0.13). Subsequently, this progress in metacognitive awareness was modeled multilevel and, as shown in Table 5, the progress in regulation of cognition is higher than in knowledge of cognition. The random part reveals that the significant variance was only situated at the student level and no significant variance was found at the group and class level. After adding condition as explanatory variable to the model, we concluded that the implementation of the collaboration script could not improve this progress. Moreover, given the nested hypothesis (goodness of fit) test, it can be stated that adding the condition variable did not result in an improvement of the model.

Table 5

Multilevel parameter estimates for the three-level analyses of students' progress in metacognitive awareness

	Knowledge of Cognition		Regulation of Cognition	
Parameter	Null Model	Script Model	Null Model	Script Model
Fixed part				
Intercept β_0	0.25* (0.05)	0.21* (0.08)	0.34* (0.06)	0.40* (0.08)
Coll. script		0.08 (0.11)		-0.13 (0.11)
Random part				
Level3- Class variance	0.02 (0.02)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)
Level 2-Group variance	0.05 (0.03)	0.05 (0.03)	0.04 (0.06)	0.04 (0.06)
Level 1-Group variance	0.26* (0.04)	0.27* (0.04)	0.54* (0.08)	0.54* (0.08)
Model fit				
Deviance	345.69	345.20	461.65	460.32
χ^2		0.49		0.49
df		1		1
p		= 0.48		= 0.24

Note. Standard errors are in parentheses. * indicates $p < 0.05$

Strategic knowledge

Students' strategic knowledge was measured by asking them to describe as clearly as possible how they performed in the IPS task and what they kept in mind during this task. Students' descriptions were scored based on the Big6 which was provided throughout the project. Regarding the six steps we coded whether students mentioned a specific step (coded 1) or not (coded 0) and if students also mentioned how and/or why this step/strategy needed to be performed (coded 2). Appendix D gives an overview of the distribution among the categories (0-1-2) of the Big6 strategies in pre-test and post-test for students in both conditions. These results show that overall this strategic knowledge was limited, with very few students mentioning how to perform a certain step (i.e. code 2), and that most students' strategic knowledge was limited to the first two steps, that is, mentioning that they would go to Google and indicate which keywords they used (Big6 - Steps 1 and 2).

Subsequently, the question arose whether the project could benefit students' progress in strategic knowledge from pre – to post-test and if this was especially the case if students were in the collaboration script condition. The progress in Big6 strategy knowledge was analyzed by three-level ordered multinomial analyses in which condition was added as an explanatory variable (see Appendix E for the multilevel parameter estimates). Although collaboration script was not found to be a significant predictor for progress in strategy knowledge, the logit parameters and the script parameter were used to calculate the estimated probabilities of students' progress per condition as depicted in Table 6. It can be seen that regarding all strategies some of the students (from 5 to 27%, depending on the strategy) made progress from pre- to post-test. Unfortunately, a number of students mentioned the strategy in the pre-test, but did not mention the same strategy in the post-test. Except for strategy 1, most students (62% and more) did not make progress.

Table 6

Estimated probabilities of students' progress in performance of the Big6 strategies (post - pre) per condition based on ordered multinomial statistics (see Appendix F)

Progress in performance of the Big6 strategies (post - pre)		-2	-1	0	+1	+2
1) Identifying information research goals	Control	8.5%	16.2%	42.7%	25.1%	7.5%
	Collaboration Script	10.2%	18.3%	43%	22.2%	6.3%
2) Seeking and selecting the best sources	Control	1.1%	18.7%	71.7%	8.6%	0%
	Collaboration Script	0.9%	15.0%	73.2%	11.0%	0%
3) Finding information within the sources – judging relevance and reliability	Control	2.5%	11.6%	70.0%	12.1%	3.8%
	Collaboration Script	2.4%	11.1%	69.9%	12.5%	4.0%
4) Using and comparing information	Control	0%	10.5%	65.0%	22.8%	1.7%
	Collaboration Script	0%	8.3%	62.2%	27.3%	2.2%
5) Synthesizing and presenting information from multiple sources	Control	0%	6.4%	73.3%	18.9%	0.5%
	Collaboration Script	0%	5.7%	71.9%	21.9%	0.5%
6) Product and process evaluation	Control	0%	0.6%	94.7%	4.3%	0.4%
	Collaboration Script	0%	0.4%	93.5%	5.5%	0.6%

Performance in argumentative writing

Students' argumentative performance was measured by the second part of the task in which they were individually asked to take up a position in the scientific debate and to formulate their claim and support this with evidence from the web. Students' positions in the scientific debate were coded using the scoring rubric displayed in Appendix C. Appendix F gives an overview of the distribution among the categories regarding this task in pre-test and post-test for students in both conditions. These results reveal that although most students take a position in the debate, the majority of the students support their claim with only one argument and only a minimum of the students reveal the source regarding their argumentation.

Subsequently, the progress in argumentative writing was analyzed using three-level ordered multinomial analyses in which condition was added as explanatory variable (see Appendix G for the multilevel parameter estimates). Again, collaboration script was not found to be a significant predictor for progress in argumentative writing. Yet the logit parameters and script parameter were used to calculate the estimated probabilities of students' progress per condition as depicted in Table 7. From this table, it can be seen that at least 15% of the students made improvements in argumentative writing as indicated by the progress percentages of students formulating the claim in their answer, giving one or more relevant arguments and revealing the source of the evidence they used in their argumentation. However, a diminution in the argumentative writing quality of some students was noticed.

Table 7

Estimated probabilities of students' progress in argumentative writing (post - pre) per condition based on ordered multinomial statistics (see Appendix G)

Position statement in debate (post - pre)		-2	-1	0	+1	+2
1) Claim	Control	/	9.9%	68.5%	21.6%	/
	Collaboration Script	/	15.3%	70.3%	14.4%	/
2) Argumentation	Control	1.3%	21.1%	39.0%	31.0%	7.6%
	Collaboration Script	1.6%	24.9%	40%	27.3%	6.2%
3) Source notification	Control	0.8%	5.4%	66.5%	27.7%	0%
	Collaboration Script	1.2%	7.4%	70.5%	20.0%	0%

Qualitative analyses

In addition to the quantitative results, qualitative data were collected with regard to the observed pairs to add nuance and contour to the study, enriching it beyond what quantitative analysis can offer. Student interactions were observed and analyzed first to gain insight into how groups in the script condition dealt with the collaboration script and how students without scripts shaped their collaboration regarding task division and role taking, and second to gain insight into the relation between the group performance of students and the performance of the Big6 information processing strategies. Students' group performance scores obtained during the

WISE project were used as a criterion to select two successful dyads (the best performing group of each condition) and two unsuccessful groups (the worst performing group of each condition.

Task division and role taking

Regarding Arne and Karel, the best performing group from the script condition, we noticed that they followed the provided script and accepted the given roles. When Karel as executer controlled the computer, Arne was also actively involved as web detective by giving suggestions on where to look when searching the web or how to formulate an answer and vice versa. At the start of a new session, they always recapped the task division:

> Arne: *“Who will type and who will pay attention to the quality?”*
> Karel: “*I ended last session as the executer.”*

Quinten and Clement, the best performing group from the no-script condition, on the other hand were not provided with a script; however, good quality and even collaboration were observed. They did not make explicit arrangements about the task division and role taking, Quinten spontaneously controlled the computer, carefully read the question/instruction (often aloud), and typed the answers. Quinten kept this role for the whole project, spread over four sessions. Yet this does not mean that Clement was less active during the sessions because he was not handling the computer (which was the case in some other groups). The next excerpt gives evidence of this even participation:

> Quinten (as executer): *"... the atmosphere, right?"*
> Clement (as web detective): *"I don’t think so…."*
> Quinten: *"It is determined by the atmosphere, no?"*
> Clement: *"Have you read this? There is a lot of information on this site but not really what we need."*
> Quinten: *"Look, I'll show you. It was here somewhere ... "*(shows Clement
> where he read it) *"So it will be right, no?"*
> Clement reads and verifies: *"I think we should write that atmospheric flow regulates the water transport."*
> Quinten thinks about it and sees that his answer is not correct. He goes back, adjusts his answer and asks whether it is good. *"Now it's good, right?"*
> Clement: *"Yes, I think so."*
> *…*
> Clement: *“Oh wait, don’t forget to add the source!”*

Clement also ensures that for each inquiry step the source is properly acknowledged and not forgotten. He also pays attention to the correct and careful formulation of the answer, which gives evidence of successful co-regulation.

Next, we provide an example of the task division and role taking within the two worst performing dyads. Although Jasper and Arnoud were provided with a collaboration script, their collaboration was characterized by an unbalanced division of tasks. They did switch the role of the executer during the project, but not when prompted by the script. Once they switched spontaneously (Arnoud: "*Next question… The sun affects… Do you want to do that, this question?*”) and once when the supervisor had prompted them to switch.

Arnoud: *"OK… Now, you are the executer."*
Jasper: *"Who will work with the mouse?"*
Arnoud: *"You… we have to change… now you are the little mouse, and I'm your little cat; here is the question,bitch."*

As the excerpt illustrates, Arnoud was often rude and really dominant in the position as executer as well as in the position as web detective. In the role of executer he decided what to write without consulting Jasper; in the role of web detective Arnoud was the one who told Jasper what to do, how to do it and what to write. Moreover, this group showed a lot of off-task behavior and loafing about; for example, beat boxing and singing during the project. The next episodes characterize these undesirable processes:

(Arnoud as executer)
Arnoud: *"OK, wait… the aim… the future of the planet… organized with reference to… conference in Copenhagen."* (Arnoud is typing the answer by thinking aloud)
Arnoud: *"And what will we… oh wait…"*
Arnoud: *"When we reviewed the reactions on the forum, we noticed that…"* (reading aloud what he is typing)
Jasper: Muttering something - unintelligible
Arnoud: *"Yes wait…"*
Arnoud: *"… that some people didn't like it, and there is no strong agreement. Voilà. Save."* (saying aloud what he is typing, he saves the answers without discussing them with Jasper)

(Jasper as executer)
Arnoud: *"No no, you won't find it there, you have to search for it on the net, and this is your question."*
Jasper: *"This?"*
Arnoud: *"No, the above one!"*
Jasper: *"And this is what we have to search for on the web?"*
Arnoud: *"On the web yes… So, try this site, yes look, it will disappear, type climate and ocean…, No! Do just Google. Yes, take this one!"*
Jasper: *"This?"*
Arnoud: *"Ah yeah… Don't you think? Imbecile."*
Arnoud: *"And next one, the atmosphere affects the climate because…, this also needs to be done."*

Moreover, it was found that this dyad did not handle the task systematically; instead of progressing the project step by step in order to achieve a good solution, they skipped certain steps, especially the evidence and display pages where they had to read the instruction or information they needed for the task, as becomes clear from the following passage:

After Arnoud had solved question 1.2 in the introductory activity, he said the following regarding the steps "Project objectives", "the Big6 plan" and "A role for each!" *"Those are not fill-in questions anymore,"* whereupon he immediately went to "Next activity". Further on in the project, they even skipped fill-in assignments. Some examples: Arnoud: *"We won't fill this in"* (activity 3, step 2); Arnoud: *"Phew .. this second part, we can skip this."* (activity 3, step 3)

The dyad consisting of Marthe and Ellen from the no-script condition on the other hand was not provided with a collaboration script, but these students spontaneously divided the tasks. The questions in the WISE project were read aloud in turn. Moreover, these students spontaneously switched the roles of typing the answers and formulating the answers. Yet the execution of the information processing strategies was very superficial, not going beyond selecting one source that could explain their answer and copy-pasting a possible answer without questioning its relevance and reliability. Consequently, they also failed to provide elaborated explanations.

> Marthe:*"I don't know what to make of it."*
> Ellen: *"I think it is because they want to change people's mind. Do you agree?"*
> Marthe: *"Yes, I agree."*
> ....
> Marthe: *"What do we have to do now?"*
> Ellen: *"Answering."*
> Marthe: *"Answering what?"*
> Ellen: *"Come on, the sun affects the climate because… "*

Information processing of successful groups versus unsuccessful groups

The information processing of the successful dyads was characterized by identifying the information research goals and activating prior knowledge before starting the information query, e.g.:

> Quinten: *"Difference between weather and climate? Ah, but I know this. Climate is measured on a bigger scale, in a larger area and weather is measured on a smaller scale, in a smaller area."*
> Clement: *"Yes, we've learned this in geography."*
> Quinten: *"Yes, but we'd better verify this by searching the web."*

They were also critical of what they found on the Internet and often revised a piece of evidence to *"make sure that we understood it right."* They helped each other to formulate a good answer and reminded each other about the task requirements: *"Maybe, we should look again at the questions."* They also activated their prior knowledge when prompted to do so: *"We first have to think a bit about the difference between weather and climate, what do you think?*"; but also did this even if it was not explicitly asked. Karel for example spontaneously told Arne what he knew about the Kyoto protocol. While searching the web they adopted a critical attitude and questioned if the site was relevant to the problem: *"This is not the difference, this is not OK, let's also take a look at this site."* They compared information of different websites until they found the information they needed to answer the question. While formulating their answer, they revised it several times: *"What do we have here already…"*

Regarding the information processing of the unsuccessful dyads, we observed that with regard to task analysis, none of the students said what the information problem was and what kind of information they needed to solve it. Although they were savvy in navigating on the web (Wikipedia, Google), they always limited themselves to a single source to answer the question without bothering to check an extra source. They did not question the reliability and usability of the information found and did not make a relevant selection; for example, in the answer to the inquiry about how the atmosphere affects climate. Although the answers were often long (copy-pasted from the source), any coherence was lacking and the dyad even did not change the formulation so that their copied text would fit the provided sentence opener: *"The atmosphere affects the climate because* (= sentence opener provided in the WISE note). *Climate researchers are trying to find out the causes of climate change, both natural changes and changes caused by humans (anthropogenic) …"* They did not reveal their source(s), although this was explicitly requested.

Discussion

Opportunities for collaborative work can support the process of information problem solving (Lazonder, 2005), including negotiating meaning, reconciling diverse sources and using valid, credible evidence, although this is not a straightforward or guaranteed outcome of collaborative work (Linn & Eylon, 2011). Strong regulation ability is necessary for successful open-ended learning environments and web-based learning specifically (Azevedo & Cromley, 2004; Brand-Gruwel et al., 2009). In the light of these issues, the present study was intended to investigate the regulatory processes that come into play when individual learners work collaboratively in solving information problems on the web and if these can be supported by providing students with a collaboration script.

Regarding the first research question, it was hypothesized that students in the script condition would yield higher socially shared regulation than students in the control condition without collaboration scripts. Unfortunately, no significant improvement in socially shared regulation was found that could be attributed to the classroom script intervention. Only a marginally significant effect was found, which indicates the trend that students in the script condition reported a higher performance of step 4, that is comparing several sources and reaching consensus about the usefulness of the source(s). Yet this is not enough evidence to confirm our hypothesis since no differences were found between the conditions regarding the other Big6 strategies. Moreover, the qualitative results derived from contrasting dyads which were selected on the basis of their group performance scores indicated no straightforward difference between the scripted and unscripted groups. However, the qualitative results shed light on possible explanations of this finding. The successful group consciously followed the script and adopted the roles as assigned, whereas the unsuccessful group in the script condition did not handle the task systematically and neglected the collaboration script. This latter group, for example, skipped certain activity steps within the project, especially the ones in which no other actions than reading were expected. Moreover, this group was characterized by unbalanced collaboration because of the rudeness and dominance of one of the group members. This is in line with previous research (Barron, 2003; Chiu & Kuo, 2009; Vauras et al., 2003) which indicated that one very distinct feature of successful collaboration is openness in terms of non-defensive ways of reacting to one's own actions, misinterpretations, or comprehension failures and to the partner's helping reactions and guidance. Non-defensiveness paves the way for mutual problem solving and shared regulation, yet this was not something which could be guaranteed by the script.

Although this finding is contrary to several studies which present positive results of a collaboration script (see e.g. Kollar et al., 2007; Rummel & Spada, 2005; Schoonenboom, 2008), it is in line with Linn and Eylon (2011), who noticed that scripting may reduce the spontaneous generation of personally unique contributions which is a potential advantage of collaboration. Moreover, Chiu and Kuo (2009) pointed out that although roles are assigned group members often mutually organize each other's role and distribute responsibilities dynamically, depending on their needs and skills. Determining a specific role for each of the participants requires that students have the skills to perform the role, but also the belief of their peers that they can perform the role. Scripted roles can fail if students are assigned roles which they cannot perform or do not feel comfortable with. It is possible that distributed responsibility for cognitive and metacognitive processes only works if each collaborator can take responsibility in his or her area of strength since there is evidence that distributed metacognition allows greater focus of attention and specialization in individual strengths, which can increase problem-solving effectiveness and efficiency (Chiu & Kuo, 2009). That is what happened in the successful group in the no-script condition in which students were given the freedom to establish their own way of working together, to divide the tasks and to build and monitor their "joint problem space". The members of this group both took a role without changing roles; however, this did not lead to unbalanced participation. Giving students more choice in taking up a role and playing according to their strengths probably leads to better results. Additionally, performing a specific role should be less free of engagement in the sense that students experience individual accountability. Yet we also have to realize that teaching metacognitive skills is difficult because of their extra cognitive demands and can discourage students from applying metacognitive strategies, especially if they do not see the importance of the task (Salonen, Vauras, & Efklides, 2005). The external script imposes an additional information processing burden that may interfere with students' focus on the information to be learned (Schraw, 2007). The web-based inquiry project already included a lot of activities and topics related to global climate change which had to be discussed and learned during a rather brief intervention time of four sessions of 50 minutes. Consistent with the reasons why the SEEK tutor of Graesser et al. (2007) did not lead to the expected results it is plausible that the intervention attempted to do too much at once. The project aimed to improve the overall information problem-solving process through a whole-task approach (Brand-Gruwel et al., 2009) including the four key regulation skills of orienting, planning, monitoring, and evaluating. It might be better to focus on a more specific goal such as source evaluation (Walraven et al., 2012) which is probably more likely to succeed during a short intervention.

Second, in line with the strong consensus that successful learners self-regulate their learning by using a repertoire of strategies while completing tasks, it was hypothesized that better shared regulation would lead to better co-constructed knowledge. This hypothesis was partly confirmed by both quantitative and qualitative results. The quantitative results revealed that one out of the six Big6 strategies (i.e. step 1. Task analysis) significantly predicted better group performances. In addition, the qualitative results showed that the information processing of the successful groups was characterized by adequate task analysis and activation of prior knowledge, revision of pieces of evidence, questioning of the relevance and reliability of the sources and comparison of different sources used in the final answer. The collaborative process of the worst performing groups on the other hand was characterized by superficial information processing, students picking the first ranked source without source evaluation and copy-pasting part of the source in the answer. These results are consistent with findings that regulative team activities can lead to better learning results (Saab et al., 2012) and with Brand-Gruwel, & Vermetten (2005), who found that compared with novices experts in IPS spend more time on the main skill ("define the problem") and more often activate their prior knowledge, elaborate on the content, and regulate their process.

Third, it was questioned if the overall implementation - and the collaboration script implementation particularly - improved students' individual metacognitive skills and if the intervention helped the students to learn more strategies and perform better in terms of argumentative writing.

It was found that the overall implementation improved students' metacognitive awareness. This is consistent with the finding that social metacognition supported by the web-based inquiry learning environment can facilitate learning of individual metacognition (Chiu & Kuo, 2009). However, no significant value was added by the collaboration script. Neither was significant added value found for students provided with a collaboration script as regards improvement in students' strategy use and students' performance in argumentative writing, which is in line with the findings regarding RQ1. It was noticed that students' strategy knowledge before the project was mostly limited to the first two steps (going to Google and typing the keywords), and only a few students also mentioned the need to check the reliability of and compare different sources and combine these sources to construct their answer. After the web-based collaborative inquiry project, more students indicated they had compared multiple sources to synthesize their answer and slightly more students indicated they had evaluated their answer before submitting it. Improved strategic knowledge and metacognitive awareness also resulted in end-products of higher quality. When students were asked to formulate their position in the scientific debate, more students provided one or more arguments to justify their claim and more students revealed the source of their arguments than in the pre-test.

However, it must be noted that in some cases information processing strategies (especially Big6 1 and 2) were mentioned in the pre-test and no longer in the post-test. Some students probably did not repeat the more "obvious" steps which they mentioned during the pre-test and only mentioned the newly familiar ones. Moreover, 70 % of the students did not reveal the source of their argumentation. The construction of evidence-based arguments remains for most students a complex task which deserves more attention (Belland, Glazewski, & Richardson, 2008; Reiser, 2004). Therefore, although it is encouraging that some of the students made progress, further research should investigate ways to allow more students to do so. As mentioned in the theoretical framework, support can be given before and during the intervention. In this study we focused on the implementation of a collaboration script in addition to embedded technology-enhanced scaffolding during the intervention, but it is questionable whether some students would benefit more if plenary instruction was given in advance. The role of the teacher was outwith the scope of this study, but is invaluable in creating and promoting classroom cultures that facilitate desirable student interactions and social metacognition. However, there is still some way to go to convince teachers not only to focus on the cognitive processes but also spend time on the metacognitive processes.

Theoretical contribution, limitations and implications for further research

This research met one of the new challenges of educational research, that of studying shared regulation during computer-supported collaborative learning (Azevedo, 2014; Chan, 2012). Moreover, this study took place in real classrooms and was conducted on a relatively large scale. Although researching authentic settings is advantageous because of the high ecological validity, there are some inherent drawbacks. As the intervention was conducted on a large scale and in a real-life context, the available time and facility to measure learning processes were limited. To obtain both generalizable results and more in-depth results, a mixed methods approach was used; yet using this method also confronted us with its shortcomings. Students' shared regulation during IPS on the web was measured quantitatively with a questionnaire in which they were asked individually to rate how they collaboratively performed the different Big6 strategies. However, the results of the multilevel analyses and the qualitative results confirmed that, next to unequal participation across groups, unequal participation in groups existed; certain students told others the answers, did the work, or dominated the others (Barron, 2003; Sampson & Clark, 2011). This unequal participation highlights the conceptual challenge of talking about shared or co-regulation in addition to self-regulation or other-regulation (Volet & Vauras, 2013). There is also a methodological challenge since it is questionable how students dealt with the questionnaire gauging shared regulation when their collaboration was characterized by uneven participation. For three out of the six Big6 strategies no significance variance was found at the group level, which indicates that students scored the way they performed a certain strategy in different ways. Regarding the qualitative analyses, the study was only based on observation and audiotaped data; no log data and tracking of non-verbal communication like pointing and eye contacts were available. However, since researchers have started to see SSRL as a series of events which can be perceived as a process that unfolds over time in a certain order (Molenaar & Järvelä, 2014), these additional process data should be collected, including the duration of each cognitive and metacognitive process, for better understanding of the nature and quality of the temporally unfolding regulative processes.

As already mentioned, another important implication for future research is the focus on the role of the teacher. Guidance from the teacher was not within the scope of this study, yet in a complex classroom support and guidance take place at different social levels (i.e. the individual, group, and classroom level) and come from different sources (Dillenbourg, Järvelä, & Fischer, 2009). Next to technology and peers, the teacher is another source which can monitor group progress. Further research should explore the interplay between multiple modes of support and guidance in everyday classrooms and how teachers can effectively mediate executive control to help less competent (or unmotivated) peers to gain shared metacognitive competence. The notion of collaboration itself presupposes task orientation, persistence and some degree of intrinsic motivation (Vauras et al., 2003), and therefore it is also important to obtain more insight into the motivational processes which are prerequisites for true cognitive partnerships. In line with this, future research should include learner characteristics and group composition based on learner characteristics as mediating variables, since it is feasible that these partly determine the interactions and learning processes established during collaborative learning (Denessen, Veenman, Dobbelsteen, & Van Schilt, 2008; Webb, Nemer, & Ing, 2006).

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Appendix A

Krippendorff's alpha reliability estimations for judgments regarding the inter-reliability of the coded variables.

Variables		Krippendorff's alpha values
Collaborative knowledge construction		
	Proces_Activity_1	0.7824
	Proces_ Activity_2	0.6712
	Proces_ Activity_3	1
	Proces_ Activity_4	0.8963
	Proces_ Activity_5	0.8242
	Proces_ Activity_6	0.7478
	Proces_ Activity_7	0.9233
	Proces_ Activity_8	0.8362
	Proces_ Activity_9	0.9863
	Proces_ Activity_10	0.8214
	Proces_ Activity_11	0.7814
Individual Pre-test		
	IPS_Pre _Big6_Step1	0.7941
	IPS_Pre _Big6_Step2	0.6246
	IPS_Pre _Big6_Step3	0.9019
	IPS_Pre _Big6_Step4	0.7751
	IPS_Pre _Big6_Step5	0.9496
	IPS_Pre _Big6_Step6	0.1626
	IPS_Pre_answer_claim	0.8236
	IPS_Pre_answer_argumentation	0.6867
	IPS_Pre_answer_source	0.9404
Individual Post-test		
	IPS_Post_Big6_Step1	0.7726
	IPS_ Post_Big6_Step2	0.2481
	IPS_ Post_Big6_Step3	0.9623
	IPS_ Post_Big6_Step4	0.7522
	IPS_ Post_Big6_Step5	0.9607
	IPS_ Post_Big6_Step6	0.8305
	IPS_ Post_answer_claim	0.7430
	IPS_ Post_answer_argumentation	0.6512
	IPS_ Post_answer_source	0.8990

Appendix B

Task to measure information problem solving skills on the web

Take up a particular position regarding the scientific controversy below (the two scientific controversy texts were counterbalanced across two groups to ensure that any differential effect was not the result of varying task difficulty). Justify your position with appropriate evidence from the web to support your claim.

Fewer pimples! Just by changing what you eat! Fact or myth?	Mobile phone radiation: harmful or nonsense!?
	

1.1 Describe in the box below as clearly as possible HOW you will perform this task and what you will keep in mind during this process.

1.2 Formulate your claim below and justify it with appropriate evidence from the web.

1.3 Fill out this questionnaire with regard to the task you have just performed.

Sample items of the two components of the adapted version of the Metacognitive Awareness Inventory (Schraw & Dennison, 1994) and the associated Cronbach's alphas

Scale	Items
Knowledge of cognition Consisted of 17 items Pre-test (α= 0.902) Post-test (α= 0.918)	• When searching the Internet for information I tried to use a method that had worked well in the past. • When I finished searching the Internet, I knew how well I had solved the information problem. • I knew what information was most important for solving the information problem. • I was good at presenting the information I had found on the Internet. • While searching the Internet for information, I deliberately turned my attention to important information.
Regulation of cognition Consisted of 15 items Pre-test (α= 0.868) Post-test (α=0.882)	• While searching the Internet for information, I often asked myself if my strategy would result in a good answer to the information problem. • I compared information from different websites before I solved the information problem. • I asked myself questions about the subject before I started searching for information on the Internet. • I asked for help when I did not understand anything when searching for information on the Internet. • Once I finished searching the Internet, I asked myself how well I had answered the information problem.

Appendix C
Scoring rubric for the information problem-solving task
(see Appendix B)

1.1 Planning the task.
Regarding every step of the “Big Six” (Eisenberg & Berkowitz, 1988) we coded whether students know the step and if they also mentioned how and why this step/strategy needed to be performed.

Score	Response description
0	When the step of the Big Six was not mentioned
1	When students mentioned the step, but did not specify how he/she would do it. e.g. I search on Google (step 1) ; I select a reliable source (step 3)
2	When students mentioned the step and added how they would perform this. e.g. I search for the effect of nutrition/food on acne by typing the keywords in Google (step 1); I select reliable information by looking at the date of the source. I only want to use information less than five years old

1.2 Answer to the task.
The answer was coded regarding the main aspects: claim, argumentation, and source indication

Answer component	Score	Response description
Claim	0	No claim is formulated
	1	The claim is clearly formulated
Argumentation	0	No argumentation
	1	Claim is justified with at least one relevant argument
	2	Claim is justified with two or more relevant arguments
Source identification	0	No reference is made to the source and/or the quality/reliability of the given argument(s)
	1	Reference is made to the source/origin of at least one argument, but the quality/reliability is not justified
	2	Reference is made to the source/origin of at least one argument and it is justified why this source is qualitative/ reliable

Appendix D

Overview of the distribution among the categories (0-1-2) of the Big6 strategies in pre- and post-test for students in the control condition and students in the collaboration script condition

Performance of the Big6 strategies		Control		Collaboration Script	
		Pre-test	Post-test	Pre-test	Post-test
1) Identifying information research goals	0	28.6%	26.5%	33.0%	38.9%
	1	30.6%	29.6%	38.4%	29.6%
	2	40.8%	43.9%	28.6%	31.5%
2) Seeking and selecting the best sources	0	77.6%	89.8%	75.9%	79.6%
	1	22.4%	10.2%	22.3%	20.4%
	2	0	0	1.8%	0
3) Finding information within the sources – judging relevance and reliability	0	81.6%	80.6%	69.6%	67.6%
	1	14.3%	15.3%	25.0%	23.1%
	2	4.1%	4.1%	5.4%	9.3%
4) Using and comparing information	0	70.4%	58.2%	75.9%	55.6%
	1	29.6%	40.8%	24.1%	40.7%
	2	0	1	0	3.7%
5) Synthesizing and presenting information from multiple sources	0	86.7%	74.5%	91.1%	74.1%
	1	13.3%	25.5%	8.9%	25.0%
	2	0	0	0	0.9%
6) Product and process evaluation	0	99%	94.9%	100%	94.4%
	1	1%	5.1%	0	4.6%
	2	0	0	0	0.9%

Appendix E

Multilevel parameter estimates for the three-level ordered multinomial analyses of students' progress in Big6 strategy use

	Big6_1		Big6_2		Big6_3		Big6_4		Big6_5		Big6_6	
	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model
Fixed part												
Logit (γ_{-2jkl})	-2.27	-2.38	-4.61	-4.48	-3.68	-3.65	/	/	/	/	/	/
	(0.24)	(0.24)	(0.70)	(0.73)	(0.45)	(0.47)						
Logit (γ_{-1jkl})	-1.02	-1.12	-1.53	-1.4	-1.83	-1.81	-2.27	-2.15	-2.78	-2.69	-5.31	-5.18
	(0.16)	(0.22)	(0.18)	(0.25)	(0.20)	(0.26)	(0.24)	(0.28)	(0.30)	(0.37)	(0.99)	(1.04)
Logit (γ_{0jkl})	0.82	0.72	2.21	2.36	1.64	1.66	0.99	1.12	1.29	1.37	2.86	3.00
	(0.15)	(0.21)	(0.24)	(0.30)	(0.19)	(0.25)	(0.16)	(0.22)	(0.17)	(0.29)	(0.31)	(0.47)
Logit (γ_{1jkl})	2.60	2.50	/	/	3.19	3.21	3.91	4.05	5.31	5.39	5.31	5.45
	(0.28)	(0.31)			(0.36)	(0.40)	(0.50)	(0.53)	(1.00)	(1.04)	(1.00)	(1.06)
Collaboration		0.20		-0.27		-0.05		-0.25		-0.12		-0.26
script (h_{jkl})		(0.28)		(0.32)		(0.30)		(0.29)		(0.87)		(0.60)
Random part												
(L3) Class		0.00		0.00		0.00		0.00		0.13		0.00
variance		(0.00)		(0.00)		(0.00)		(0.00)		(0.17)		(0.00)
(L2) Group		0.25		0.20		0.00		0.00		0.00		0.00
variance		(0.27)		(0.37)		(0.00)		(0.00)		(0.00)		(0.00)

Note: (Ref. category = highest progress, i.e. in most cases +2)

Appendix F

Overview of the distribution among the categories regarding the quality of students' formulated positions in the debate in pre- and post-test for students in the control condition and students in the collaboration script condition

Position statement in debate		Control		Coll. Script	
		Pre-test	Post-test	Pre-test	Post-test
1) Claim	0	30.2%	18.6%	18.1%	18.1%
	1	69.8%	81.4%	81.9%	81.9%
2) Argumentation	0	27.1%	12.4%	22.9%	9.5%
	1	42.7%	54.6%	50.5%	62.9%
	2	30.2%	33.0%	26.7%	27.6%
3) Source notification	0	93.8%	72.2%	81.0%	69.5%
	1	6.3%	27.8%	17.1%	30.5%
	2	0	0	1.9%	0

Appendix G

Multilevel parameter estimates for the three-level ordered multinomial analyses of students' progress in argumentative writing

	Claim		Argumentation		Source notification	
	Null Model	Script Model	Null Model	Script Model	Null Model	Script Model
Fixed part						
Logit (γ_{-2jkl})	/	/	-4.20 (0.58)	-4.33 (0.60)	-4.61 (0.70)	-4.80 (0.73)
Logit (γ_{-1jkl})	-1.92 (0.21)	-2.21 (0.28)	-1.12 (0.16)	-1.24 (0.21)	-2.53 (0.27)	-2.71 (0.34)
Logit (γ_{0jkl})	1.53 (0.18)	1.29 (0.23)	0.58 (0.15)	0.46 (0.20)	1.45 (0.16)	0.98 (0.25)
Logit (γ_{1jkl})	/	/	2.60 (0.28)	2.50 (0.31)	/	/
Collaboration script (h_{jkl})		0.49 (0.30)		0.23 (0.26)		0.34 (0.35)
Random part						
(L3) Class variance		0.00 (0.00)		0.00 (0.00)		0.00 (0.00)
(L2) Group variance		0.00 (0.00)		0.06 (0.24)		0.00 (0.00)

5 Unraveling the motivational effects and challenges of web-based collaborative inquiry learning across different groups of learners

This chapter is based on:

Raes, A. & Schellens, T. (2015). Unraveling the motivational effects and challenges of web-based collaborative inquiry learning across different groups of learners. Educational Technology Research & Development, 63; 405-430. doi: 10.1007/s11423-015-9381-x

Chapter 5
Unraveling the motivational effects and challenges of web-based collaborative inquiry learning across different groups of learners

Abstract

This study deals with the implementation of a web-based collaborative inquiry (WISE) project in secondary science education and unravels the contribution and challenges of this learning approach to foster students' motivation to learn science, and its relation with student and class-level characteristics. An empirical mixed methods study in 13 secondary science classes was conducted, involving 220 students. Students' motivation was quantitatively studied based on the self-determination theory, and it was hypothesized that web-based collaborative inquiry can be considered as a need-supportive environment, which in turn can foster autonomous motivation and decrease controlled motivation. In addition, qualitative analyses were conducted on students' experiences and future preferences regarding the WISE project. It was found that the hypothesis of an increased autonomous motivation only holds for general track students. Moreover these students were significantly more positive about web-based inquiry in science education compared to students from a science track. To conclude, we describe how the learning environment can be improved to satisfy students' basic needs and improve good quality motivation for science learning.

Introduction

According to the self-determination theory (SDT; Deci & Ryan, 2000), to be motivated means to be moved to do something, and motivated people are energized and activated to the end of a task. Yet, unfortunately several studies notice decreased motivation for science learning and decreasing numbers of students considering pursuing scientific studies or a career in science (e.g., Osborne, Simon, & Collins, 2003). Since motivation is not considered to be a general trait, but assumed to be situated and changeable as a function of instruction and activities that take place in a classroom (Bonney, Kempler, Zusho, Coppola, & Pintrich, 2005), the finding of decreased learning motivation has been one of the driving forces for developing and implementing innovative learning environments including web-based collaborative learning environments (Wang & Reeves, 2006). Such environments are often perceived as motivating because of the features they offer as exemplified by Liu, Horton, Olmanson, and Toprac (2011). Their study presented both quantitative and qualitative evidence that the majority of the sixth graders who were part of the study were motivated to learn with a new media enriched problem-based learning environment which creates challenges, curiosity, control, and relatedness in the curricular experience. Yet, as Mayer (2011) noted certain researchers also have stressed the increased demands on learners. Problem-solving environments rely heavily on students' ownership over their learning (Kirschner, Sweller, & Clark, 2006) and hypermedia environments more specifically depend on students' self-regulation skills that are often limited (Brand-Gruwel, Wopereis, & Walraven, 2009). An important question in this regard is if web-based collaborative inquiry can improve students' motivation to learn science, and more importantly, how web-based collaborative inquiry should be implemented to motivate different groups of students to learn science.

By specifying the contextual environments and need satisfaction that foster optimal learning, the self-determination theory is a relevant framework for unraveling the motivational effects and challenges of web-based collaborative inquiry in authentic classroom contexts. This framework has been successfully used by van Loon, Ros, and Martens (2012) who investigated the balance between autonomy and structure in a hypermedia environment. Consistent with previous research studies (Jang, Reeve, & Deci, 2010; Sierens, Vansteenkiste, Goossens, Soenens, & Dochy, 2009), they found that it is the combination of autonomy and structure that produces positive effects on both intrinsic motivation and learning outcomes. Yet, a limitation of this study was that students learned individually and that the teacher had no active role during the task. Consequently, although SDT identifies three essential psychological needs, this study did not take into account the need for relatedness, which is something that needs further research.

Next to this, it is crucial to get insight into the interplay between individual differences and the way students experience a technology-enhanced intervention (Kim & Hannafin, 2011). Research is needed to examine how affordances of student-centered, web-based learning are utilized and negotiated individually, based on unique needs and goals (Hannafin, Hannafin, & Gabbitas, 2009). Yet, research that investigates the motivational effects of web-based science inquiry in relation with student and class characteristics is underexposed (Park, Khan, & Petrina, 2009). In this regard, this study tries to fill the gaps in existing research by focusing on the motivational effects and challenges of web-based collaborative learning from an SDT perspective including the three basic needs: autonomy, competence, and relatedness. Moreover, in order to add to previous research in this area which often involves only a small number of students (Wang & Reeves, 2006), this implementation study included a (relatively) large group of students and compared the impact on different groups of students using a mixed methods approach. In this respect, this study meets the research gap of limited research that gains insight into the interplay between individual differences and the way students experience a technology-enhanced intervention (Kim & Hannafin, 2011).

The Self-Determination perspective

A qualitative view on motivation

There are several motivation theories and different conceptualizations of motivation (e.g., self-efficacy theory (Bandura, 1977), achievement goal theory (Ames & Archer, 1988), and expectancy-value theory (Wigfield & Eccles, 2000)), yet the self-determination theory (SDT; Deci & Ryan, 1985) is a motivation theory that has received an exponential increase in attention in the literature over the last decade (De Naeghel, 2012; van Loon et al., 2012). SDT has been established as a well-validated and coherent framework for the conceptualization and investigation of motivation in education in general (e.g., Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009) and science education more particularly (Lavigne, Vallerand, & Miquelon, 2007). SDT also provides theoretical grounds for examining how the social context of a learning environment can influence the motivation for a student's experience. According to Deci and Ryan's SDT and as depicted in Figure 1, motivation is a multifaceted concept as students not only vary in their levels of motivation (i.e., the amount of motivation), but also with regard to the orientation of that motivation (i.e., qualitatively different types of motivation).

Motivation can be distributed along a continuum from low to high levels of self-determination. The most self-determined style of motivation, situated at the right side of the continuum, is intrinsic motivation. In addition, several types of extrinsic motivation have been proposed each with a different degree of self-determination. The subcomponents, intrinsic motivation and internalized extrinsic motivation, refer to autonomous motivation; the combination of external and introjected regulation refers to controlled motivation (Vansteenkiste et al., 2004). Previous research within the SDT tradition has shown that an autonomous, relative to a controlled, regulation of study activities is associated with various positive learning outcomes (Reeve, Deci, & Ryan, 2004). Moreover, regarding science education more particularly, it was found that the more self-determined students' science motivation is, the more likely they consider an education and a career within a scientific field (Lavigne et al., 2007). In line with these results, Vansteenkiste et al. (2009) introduced four motivational profiles: a good quality motivation group (i.e. high autonomous, low controlled motivation); a poor quality motivation group (i.e. low autonomous, high controlled motivation); a low quantity motivation group (i.e. low autonomous, low controlled motivation); and a high quantity motivation group (high autonomous, high controlled motivation). It has been found that high school and college students in the good quality motivation group display the most optimal pattern of education outcomes (Vansteenkiste et al., 2009). In this respect, autonomous motivation needs to be fostered and controlled motivation needs to be suppressed since this will lead to a good quality motivation.

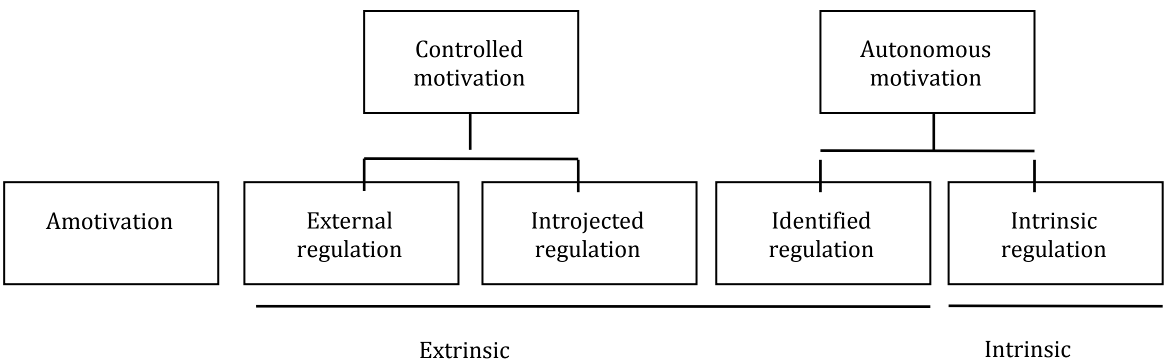

Figure 1. The SDT-continuum based on Deci and Ryan (2000).

Basic Need Satisfaction

As depicted in Figure 2, within the framework of SDT, it is maintained that teachers foster autonomous motivation when they create an environment that facilitates the satisfaction of three basic needs: students' need for autonomy, competence, and relatedness (Vansteenkiste et al., 2009). First, teacher autonomy support involves the offering of choice, the minimization of controlling language, and the provision of a meaningful rationale (Deci, Eghrari, Patrick, & Leone, 1994). Second, the need to feel competent can be supported by the provision of structure. Teacher structure involves the provision of optimal challenging tasks, praise, encouragement after failure, and adequate help, as well as the communication of clear guidelines and expectations with respect to the task that needs to be accomplished (Reeve, 2002). Finally, to meet the third basic need of relatedness, the provision of involvement is important, which refers to the experience of a sense of closeness and friendship with one's student peers (Vansteenkiste et al., 2009).

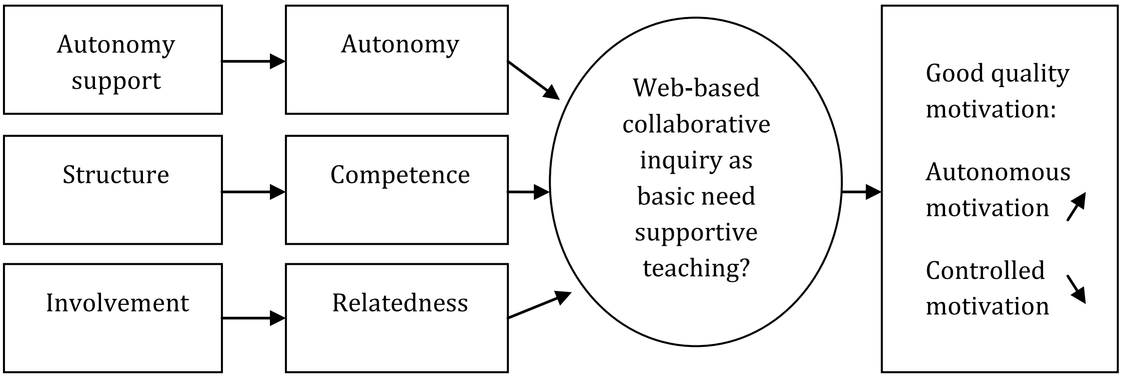

Figure 2. Teaching dimensions supporting students' basic need satisfaction and hence encouraging autonomous motivation and decreasing controlled motivation. (Based on Reeve (2009))

Web-based collaborative inquiry as perceived-need supportive teaching?

This study put forth web-based collaborative inquiry by means of the Web-based Inquiry Science Environment (further referred to as WISE) (Slotta & Linn, 2009) as a particular learning approach that can be perceived as need-supportive because of the features that may foster good quality motivation, that is, increased autonomous motivation and decreased controlled motivation for science learning.

First, based on Black and Deci (2000), inquiry-based learning in general can be considered as autonomy supportive since it is a student-centered learning approach. Students are guided and encouraged by the teacher to get involved in a social, active, engaged, and constructive learning process and perform learning tasks in their own way. This is opposed to more traditional teacher-centered approaches, which are often characterized by knowledge transmission, directing students' learning process, and the tendency to emphasize the memorization of factual information. In web-based collaborative inquiry (Chang, Sung, & Lee, 2003) and the WISE environment more particularly (Slotta & Linn, 2009), the Web is used as a source for inquiry in science, which offers students more responsibility in selecting resources to build up their knowledge and connect new knowledge with existing knowledge. The nonlinear, associative, and interactive capabilities of hypermedia can allow students to access information according to their own learning needs, and present multiple related problems in one environment (Hoffman & Richie, 1997). Yet, an increased degree of freedom can also cause discomfort to students, and this brings us to the second basic need.

The need for competence concerns people's inherent desire to be effective in dealing with the environment (Deci & Vansteenkiste, 2004). Kirschner et al. (2006) warned in their article against the pitfalls of un-guided or minimally guided instructional approaches, but although web-based inquiry is a student-centered approach offering more responsibility to students, this does not mean students are left to fend for their own devices. There is a huge amount of research focusing on the scaffolding issue (Raes, Schellens, De Wever, & Vanderhoven, 2012; Davis & Miyake, 2004; Reiser, 2004), which resulted in the assumption that supporting multiple students in a technology-enhanced classroom can best be done through distributed scaffolding with multiple modes of support with each its own unique affordances (McNeill & Krajcik, 2009; Puntambekar & Kolodner, 2005; Tabak, 2004). In the WISE learning environment more specifically, technology-enhanced scaffolding is provided through a navigation inquiry map, embedded question prompts, and computer-based feedback. Next to this, the teacher should act as a "leader from within," meaning that a teacher not only monitors students, but also actively engages the students, helps them to synthesize their views, and maintains a dynamic process of exchange within the classroom (Slotta & Linn, 2009).

Third, the need for relatedness concerns the universal propensity to interact with, be connected to, and experience caring for other people (Baumeister & Leary, 1995). Most research on relatedness focuses on the influence of parents and teachers, but it is equally important to consider the influence of peers on students' engagement, motivation, and academic achievement (Ryan & Deci, 2000). Within WISE, collaboration and interaction are highly valued since students are encouraged to learn from each other in collaborative activities, including debate, creating a group artifact, and constructing an argument (Slotta & Linn, 2009).

Although, as described above, the WISE learning environment has several characteristics to meet students' basic needs, it is rather unclear how students experience a WISE intervention regarding autonomy, competence, and relatedness support. Next to this it is crucial to get insight into the interplay between individual differences and the way students experience the technology-enhanced intervention (Kim & Hannafin, 2011). Since previous research has been found that different types of support (e.g., teacher-enhanced scaffolds vs. technology-enhanced) are proven effective for different types of learners, also the experienced balance between the provision of autonomy and structure will probably correlate with individual and class characteristics. This study aimed to get some more insight in these issues.

Research questions and hypotheses

Since in-depth, large scale motivational research based on the self-determination perspective and with a focus on the relation with student and class-level characteristics is lacking, this research tries to meet this gap by investigating the following research questions:

1. What are the effects of the implementation of WISE on student motivation for science learning (autonomous and controlled motivation)?
2. To what extent are the motivational effects related with student and class-level characteristics?
3. Does more qualitatively motivated students achieve higher learning outcomes?
4. How do students experience the WISE intervention regarding the need for autonomy, competence, and relatedness, and what are students' future preferences regarding WISE?
5. To what extent are students' experiences and future preferences related with student and class-level characteristics?

Regarding research question 1 and 3, based on previous research and due to its perceived-need supportive characteristics, it is hypothesized that Web-based collaborative inquiry can increase students' autonomous motivation to learn science and decrease students' controlled motivation. Next to this, it is hypothesized that more qualitatively motivated students achieve higher learning outcomes. Research questions 2, 4, and 5 are more explorative, aiming to inform future WISE interventions.

Method

Context and participants

This study is embedded in a larger research project that extends over five years and aims to contribute to three science outcomes: that is, knowledge acquisition, inquiry skills, and motivation for science. After a pilot study and a first iteration (see Raes, Schellens, & De Wever, 2014), this particular study contains data collected through the second iteration in order to refine our understanding of the motivational issues.

The participants in this study were 220 students from 13 secondary school classes (grade 9 and 10). The average age of these students was 16 years. The ratio of males to females among the participants was 63% boys to 37% girls. The classes were selected from six secondary schools and were a mix of differentially tracked class types (general, i.e., the track without a focus on science in their curriculum vs. science, i.e., the academic track with a focus on science in their curriculum). Eight classes followed a science track (N = 140 or 63.6%) and five classes followed a general track (N = 80 or 36.4%). Per class, students were categorized as low- or high-achiever in science based on the median exam score for sciences.

To enable a large scale implementation in authentic classrooms, this research project is set up in the context of a collaboration between science teachers in secondary education and a Master's degree program in Educational Studies at Ghent University. The science teachers were asked to dedicate a minimum of four class periods of 50 minutes to complete the intervention. Because the intervention had to be carried out according to a set of instructional principles and a strict protocol, but the science teachers did not have the time to go through a training period beforehand, it was decided to involve 34 Master's students to conduct and support the implementation of the WISE project. Thus, the Master's students served as the actual teachers during the project, whereas the regular classroom teachers predominantly observed the learning processes. For these Master's students, this assignment was a formal part of the 7-credit university course in educational technology. All Master's students underwent thorough preparatory training, which was organized in two phases. First, students experienced the learning environment and the particular project from the learner's perspective, and the first author modeled the role of the teacher. Second, Master's students experienced the learning environment from the teacher's perspective by developing a curriculum project using the underlying knowledge integration approach (see below). The training did not explicitly focus on autonomy-supportive teaching. The 34 Master's students were divided across the 13 classes participating in this study, resulting in eight classes supported by three Master's students each and five classes supported by two Master's students each. Treatment validity was checked by means of logbooks and a questionnaire that was sent to the actual teacher.

The web-based inquiry science project

Along the lines of the knowledge integration approach (Linn & Eylon, 2011), WISE was developed at the University of California, Berkeley. WISE is a powerful online platform for designing and implementing science inquiry activities. The WISE authoring environment was used to create a new curriculum project that was closely tied to the regular curriculum and was integrated with teaching and learning practices in educational practice. Global warming and climate change was chosen as the topic under investigation. For more details about the design, content, and instructional guidelines of the project see Raes et al. (2014).

Procedure

Before students started the global climate change project, they completed an individual pretest. Afterward, they were free to choose a partner and completed the WISE project with this partner. The Master's students had been trained to take over the role of the teacher during the lessons and act as a "leader from within" instead of a "guide on the side." A leader from within not only monitors students but also actively engages the students, helps them to synthesize their views, and maintains a dynamic process of exchange within the classroom (Slotta & Linn, 2009). After each lesson, Master's students provided electronic feedback (both positive and critical) through the feedback tool of WISE. After completing the curriculum project, all students completed an individual post-test.

Measures

Motivation questionnaire

Students' motivation for science learning was measured quantitatively based on the SDT perspective by means of an adapted version of the Academic Self-Regulation Questionnaire originally developed by Ryan and Connell, 1989, yet redesigned by Vansteenkiste et al. (2009). The questionnaire consists of 16 items, four items per regulation type, which could be rated on a five-point Likert scale, ranging from one (totally disagree) to five (totally agree). An example item for each regulation type and the corresponding Cronbach's alphas can be found in Table 1. This questionnaire has been successfully used and validated in the context of previous motivation research (De Naeghel, Van Keer, Vansteenkiste, & Rosseel, 2012; Vansteenkiste et al., 2009). In this study, the questionnaire was presented twice to the involved students. This pre- and post-test design was used to assess potential changes in the quality of motivation.

Table 1

Example items for each regulation type measured by means of the Academic Self-Regulation Questionnaire (developed by Ryan and Connell (1989), redesigned by Vansteenkiste, et al. (2009))

Question in pre- and post-test: *I'm motivated for science learning…*	Cronbach's alpha pre	Cronbach's alpha post
Controlled regulation	.716	.851
External regulation / external obligation	.734	.851
… because that's what others expect me to do.	1 2 3 4 5	
Introjected regulation / internal obligation	.509	.791
… because I want others to think I'm smart.	1 2 3 4 5	
Autonomous regulation	.925	.939
Intrinsic motivation / pleasure	.927	.924
… because it's an exciting thing to do.	1 2 3 4 5	
Identified regulation / personally relevant	.832	.875
… because it is personally important to me.	1 2 3 4 5	

Science knowledge test

Learning performance in this study was measured by students' understanding of the various scientific concepts introduced in the WISE project. The test consisted of three items asking students to first answer a multiple-choice question and then to explain the scientific idea behind their answer, and was scored on a rubric from zero to four. These items were selected from the test which was used in previous studies (Raes, Schellens, De Wever, & Vanderhoven, 2012; Raes, Schellens, & De Wever, 2014). The answers to the knowledge test were coded by two independent raters who were both trained to use the rubric. The first rater coded the answers of all students and these were used for data analyses. To check the inter-rater reliability, a second rater independently coded the answers of 30% of the students. Regarding all items, Krippendorff's alpha ranged from 0.64 to 1, which indicates good to excellent inter-rater agreement.

Open ended evaluation question

At the end of the survey, students were asked if they would like to be taught science in the same manner in future science education. Students were asked to explain in their own words why they would, would not, or under which circumstances they would like this.

Data analysis

Quantitative analysis

Since the students worked together in small groups and these groups originated from existing classes, the problem under investigation has a clear hierarchical structure. This implies that individual observations are generally not fully independent because of selection processes and owing to the common history and experiences individuals share by being part of the same group (Hox, 1994). In this respect, the analysis of test data at an individual level raises a methodological issue frequently discussed in educational research (De Wever, Van Keer, Schellens, & Valcke, 2007). Accordingly, multilevel modeling can be suggested as an alternative and adequate statistical approach.

Because of the pre- and post-test design used in this study, the data are seen as repeated measures on individuals over time. Consequently, a four-level structure arose: test time (level 1) clustered within students (level 2), which are nested within dyads (level 3), which in turn are nested within classrooms (level 4).

The software MLwiN 2.23 for multilevel analysis was used to analyze the hierarchical data, and the multilevel models were estimated with the iterative generalized least squares (IGLS) procedure in order to build and compare the models. The following procedure was used to analyze the effects of student and class-level characteristics on students' motivation for science. First, a four-level conceptual null model was built which serves as a baseline model. This unconditional null model without any predictor variables provides both the overall motivation before the intervention and the overall change in motivation after being exposed to the intervention for all students across all groups and classes. Moreover, by means of the intraclass correlation (ICC), this null model answers the question if the outcome measures vary among students, across groups, and across classes. Second, the three main explanatory variables—gender, achievement level, and academic track—were added stepwise to the fixed part of the model, and cross-level interactions were allowed between student and class-level characteristics.

For research question three investigating the connection between motivation and learning performance, linear regression analysis was conducted with motivation post-test scores as the predictor, and science knowledge post-test scores as the dependent variable, including the science knowledge pre-test scores as covariate.

The additional evaluation question in the survey was finally analysed by means of the Pearson's chi-squared test to investigate if the frequency distribution of the categorical variable with three categories (yes – no – only if) significantly differs based on student characteristics and the class characteristic academic track.

Qualitative analysis.

In addition to the quantitative analysis, the students' clarifications in their own words were analyzed using textual data analysis. First, the textual data were explored inductively by an independent coder—who was, however, familiar with the underlying theoretical basis—using content analysis to generate categories. The inductive process of identifying analytical categories as they emerge from the data was based on the grounded theory (Glaser & Strauss, 1967). The data were read and reread to identify and index students' clarifications. Second, the categories and corresponding quotes of the students have been checked independently by both authors. Krippendorff's alpha ranged from 0.78 to 1, which indicates good to excellent inter-rater agreement. Finally, the first author ordered the categories based on the frequency of quotes within each category. It was possible that a student's comment could be categorized in more than one category. For example, "It's more fun to work autonomously instead of passively sitting in the class without doing something and I'm always happy to work with the pc," fit the category, "Active and autonomous learning," and the category, "Use of technology."

Results

Unraveling students' autonomous motivation

The models that were built following the stepwise procedure, as described above, are presented in Table 2.

Conceptual null model

Based on the fixed part of the conceptual unconditional null model, we can state that before the intervention, students' autonomous motivation for science learning across all students, groups, and classes was 2.99 (0.17) on a 5-point Likert scale (= intercept β_0) and that no significant change was found after the intervention (= slope β_1, i.e. -0.01 (0.07)). These results, however, only tell a part of the story since no differentiation is made based on student and class-level characteristics. The random part of the null model informs us about the distribution of the variance of the pre-test scores as well as the variance of the change across the different levels. The total variance of the pre-test scores is 0.96, which is the sum of the between-classes (level 4) variance (= 0.29), the within-class, between-groups (level 3) variance (= 0.23); and the within-group, between-students (level 2) variance (= 0.44). After calculation of the ICC, we can state that 30% (ICC=.29/(.29+.23+.44)=.30) of total pre-test variance lies at class level, the proportion variance due to difference between groups is 24%, and finally 46% of total variance lies at student level. As depicted in Table 2, these variances in pre-test scores on the three levels are significantly different from zero at the p <.001 level, which justifies the application of multilevel analysis. Next to this, also the design effect values, which are influenced by the ICC, and the average cluster size were calculated. The design effect regarding level 4 class and level 3 group (DE = 1+((120/12)-1)*(.30)= 3.7) also indicates the need for multilevel modeling (Peugh, 2010). Yet, the design effect regarding level 3 group and level 2 student (DE = 1+((220/120)-1)*(.24)= 1.2) is lower than 2.0, and would suggest to exclude the group level from the model. However, in the case of dyadic data, the ICC would have to be 1.0 in order for the design effect to be 2, and thus, this implies that one never needs to use HLM with dyadic data. Since there is growing literature and an interest in such models, we decided to keep the multilevel structure.

With respect to the variance in change, we only find a significant variance on the student level (ICC = .85), that is 85.82% between student variance. Moreover, a significant, negative covariance between pre-test and change at the student level indicates that students starting with a lower initial autonomous motivation generally make more progress from pre- to post-test and vice versa.

Table 2
Multilevel parameter estimates for the four-level analyses of students' autonomous motivation

Parameter	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed part						
Intercept β_0	2.99 (0.17)	2.99 (0.17)	3.05 (0.18)	3.33 (0.12)	3.41 (0.13)	3.53 (0.15)
Change in motivation β_1	-0.01 (0.07)	-0.01 (0.07)	-0.01 (0.07)	-0.09 (0.06)	-0.10 (0.07)	-0.14 (0.08)
Girl		-0.10 (0.13)			-0.24 (0.15)	
Girl*Change		0.04 (0.09)			0.02 (0.11)	
Low			-0.19 (0.10)			-0.36*(0.13)
Low*Change			0.04 (0.08)			0.09 (0.10)
General track				-0.97* (0.20)	-1.15* (0.22)	-1.22* (0.23)
General track*Change				0.24* (0.11)	0.23 (0.13)	0.32* (0.13)
Girl*General track					0.48 (0.26)	
Girl*General track*Change					0.04 (0.18)	
Low*General track						0.41 (0.22)
Low*General track*Change						-0.13 (0.17)
Random part						
Level 4 - Class						
Intercept/intercept (σ^2_{f0})	0.29* (0.14)	0.29* (0.14)	0.31* (0.15)	0.07 (0.05)	0.06 (0.05)	0.07 (0.05)
Change/ Change (σ^2_{f1})	-0.07 (0.04)	-0.07 (0.04)	-0.07 (0.04)	-0.01 (0.02)	-0.01 (0.02)	-0.01 (0.02)
Change/intercept (σ^2_{f10})	0.02 (0.02)	0.024 (0.02)	0.03 (0.02)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
Level 3 - Group						
Intercept/intercept (σ^2_{v0})	0.23* (0.07)	0.23* (0.07)	0.24* (0.07)	0.23* (0.07)	0.24* (0.07)	0.25* (0.07)
Change/ Change (σ^2_{v1})	-0.04 (0.04)	-0.04 (0.04)	-0.03 (0.04)	-0.04 (0.04)	-0.03 (0.04)	-0.03 (0.04)
Change/intercept (σ^2_{v10})	0.03 (0.04)	0.03 (0.04)	0.03 (0.04)	0.03 (0.04)	0.03 (0.04)	0.02 (0.04)
Level 2 - Student						
Intercept/intercept (σ^2_{u0})	0.44* (0.06)	0.44* (0.06)	0.42* (0.06)	0.44* (0.06)	0.42* (0.06)	0.41* (0.06)
Change/Change (σ^2_{u1})	-0.09* (0.04)	-0.09* (0.04)	-0.09* (0.04)	-0.09* (0.04)	-0.09* (0.04)	-0.09* (0.04)
Change/intercept (σ^2_{u10})	0.33* (0.04)	0.33* (0.05)	0.34* (0.05)	0.34* (0.05)	0.34* (0.05)	0.34* (0.05)
Level 1 – Test time						
Intercept/intercept (σ^2_{e0})	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Model fit						
-2*log likelihood (Deviance)	922.810	922.103	912.789	908.793	904.677	894.898
χ^2		.71	10.02	14.02	4.12	13.89
df		2	2	2	4	4
p		.70	<.01	< .001	.39	<.01
Reference model		Model 0	Model 0	Model 0	Model 3	Model 3

Note. Standard errors are in parentheses. * p<.05

Student and class characteristics

In the next step, students' background characteristics - gender, achievement level, and academic track - were included in the fixed part of the model as main effects to investigate the effect on students' pre-test scores and in interaction with the test time variable to investigate its effect on students' change in motivation. Only academic track was found to be a significant predictor of students' autonomous motivation. A main effect of academic track regarding students' autonomous motivation for science prior to the intervention was found (χ^2 = 23.47, *df* = 1, p < .001), indicating that general track students' autonomous motivation for science is significantly lower than the motivation for science reported by science track students. Yet, we also found a significant main effect for academic track regarding the change in motivation after the intervention (χ^2 = 5.14, *df* = 1, *p* < .05). These results are confirmed by the multilevel effect size calculated by means of the proportional reduction in variance statistic (Peugh, 2010). The proportional reduction in level-4 intercept variance that resulted from the unconditional model (σ^2_{f0} = .29) and model 3 that included track (σ^2_{f1} = .07) indicated a variance decrease of 75% (i.e. (.29 - .07)/.29=.75). The proportional reduction in level-4 change variance is 85% (i.e. (.07-.01)/.07=.85). Including this variable results in a model that significantly fitted better to the data than the null model (χ^2 = 14.02, *df* = 2, *p* < .001). These results imply that although general track students had a significantly lower motivation for science prior to the intervention, these students realized a significant improvement in motivation, whereas science track students' motivation -which was already high - has not significantly changed.

Subsequently, cross-level interactions were added to the model (i.e. gender*academic track in model 4 and achievement level*academic track in model 5). The interaction between gender and academic track as main effect as well as the interaction effect with test time were not found to be significant predictors, and this model modification did not lead to a better model fit (χ^2 = 4.12, *df* = 4, *p* =.39). With regard to the interaction between achievement level and academic track, it was found that although the interaction variable was not a significant predictor as main effect nor as interaction effect with test time, adding this variable resulted in a significantly better model fit (χ^2 = 13.89, *df* = 4, *p* <.01). Adding this interaction resulted, however, in only a small proportional reduction in level-2 intercept variance of 6% (i.e. (.44-.41)/.44=.06).

Unraveling students' controlled motivation

The same stepwise procedure was followed to build the models - as presented in Table 3 - to predict controlled motivation.

Conceptual null model

Based on the fixed part of the four-level unconditional null model we can state that before the intervention students' controlled motivation for science learning across all students, groups and classes was 1.56 (0.05) (= intercept β_0) and that no significant change was found after the intervention (= slope β_1, i.e. 0.08 (0.05)). Based on the random part of the four level null model, however, we can indicate that regarding the pre-test scores as well as the change in motivation, the significant variance is only situated at student level (80.83 %, i.e. ICC=.80 and 95.90%, i.e. ICC=.95 respectively). Moreover, a significant, negative covariance between pre-test and change at the student level was found which indicates that students starting with a lower initial controlled motivation generally make more change from pre- to post-test and vice versa. Since no significant variance was found at the other levels, there was no need to keep the class and group level in the model (see Model 0 (4-level) in Table 3). Consequently, the modeling process has been continued with the two-level model (see Model 0 (2-level) in Table 3). Different from the four-level model, this two-level unconditional null model predicts a small but significant increase (i.e. 0.08 (0.04), *p* <.05) of controlled motivation across all students.

Table 3
Multilevel parameter estimates for the four and two-level analyses of students' controlled motivation

Parameter	Model 0 (4-level)	Model 0 (2-level)	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed part							
Intercept β_0	1.56 (0.05)	1.56 (0.03)	1.59 (0.04)	1.55 (0.05)	1.47 (0.04)	1.51 (0.05)	1.46 (0.06)
Change in motivation β_1	0.08 (0.05)	0.08* (0.04)	0.11* (0.05)	0.04 (0.05)	0.04 (0.04)	0.04 (0.05)	0.01 (0.07)
Girl			-0.10 (0.07)			-0.10 (0.08)	
Girl*Change			-0.08 (0.08)			-0.02 (0.09)	
Low				0.02 (0.07)			0.03 (0.08)
Low*Change				0.08 (0.07)			0.05 (0.09)
General track					0.23* (0.07)	0.25* (0.09)	0.22* (0.10)
General track*Change					0.12 (0.07)	0.21* (0.10)	0.08 (0.11)
Girl*General track						-0.03 (0.14)	
Girl*General track*Change						-0.20 (0.15)	
Low*General track							0.11 (0.16)
Low*Generaltrack*Change							0.06 (0.14)
Random part							
Level 4 - Class							
Intercept/intercept (σ^2_{f0})	0.008 (0.01)						
Change/ Change (σ^2_{f1})	0.001 (0.01)						
Change/intercept (σ^2_{f10})	0.01 (0.01)						
Level 3 - Group							
Intercept/intercept (σ^2_{v0})	0.04 (0.02)						
Change/ Change (σ^2_{v1})	0.00 (0.00)						
Change/intercept (σ^2_{v10})	0.00 (0.00)						
Level 2 - Student							
Intercept/intercept (σ^2_{u0})	0.21* (0.03)	0.26* (0.03)	0.26* (0.02)	0.26* (0.03)	0.25* (0.02)	0.25* (0.02)	0.25* (0.02)
Change/Change (σ^2_{u1})	-0.05* (0.02)	-0.05* (0.02)	-0.05* (0.02)	-0.05* (0.02)	-0.06* (0.02)	-0.06* (0.02)	-0.06* (0.02)
Change/intercept (σ^2_{u10})	0.28* (0.03)	0.29* (0.03)	0.29* (0.03)	0.29* (0.03)	0.29* (0.03)	0.29* (0.03)	0.29* (0.03)
Level 1 – Test time							
Intercept/intercept (σ^2_{e0})	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Model fit							
-2*log likelihood	655.77	663.81	659.95	660.17	648.36	641.22	641.89
χ^2			3.86	3.64	15.45	7.14	6.46
df			2	2	2	4	4
p			.14	.16	< .001	.12	.16
Reference model			Model 0	Model 0	Model 0	Model 3	Model 3

Note. Standard errors are in parentheses. * p<.05

Student and class characteristics

In line with the modeling of autonomous motivation, also regarding controlled motivation only academic track was found to be a significant predictor of students' motivation. A main effect of academic track regarding students' controlled motivation for science prior to the intervention was found (χ^2 = 10.62 *df* = 1, *p* < .01), indicating that general track students' controlled motivation for science is significantly higher than the motivation for science reported by science track students. No significant main effect for academic track was found regarding the change in controlled motivation after the intervention (χ^2 = 2.51, *df* = 1, *p* = .11) which was however the case for autonomous motivation. Including academic track as an explanatory variable in the model results in a model that significantly fitted better to the data than the null model (χ^2 = 15.46, *df* = 2, *p* < .001). The proportion reduction in variance used to calculate the multilevel effect size however showed that the level-2 intercept variance only decreased by 4%. Adding the cross-level interactions in model 4 (i.e. gender*academic track) and model 5 (i.e. achievement level*academic track) in a subsequent step did not lead to additional significant predictors and neither to a better model fit as indicated in Table 3.

Motivation and science knowledge

The linear regression analysis, examining the relationship between students' motivation scores and their science knowledge post-test scores, controlling for the effect of the pre-test scores, showed that both autonomous and controlled motivation are significant predictors for learning performance, but the effect is found in different directions. Whereas higher autonomous motivation predicts a higher learning performance (β = .90, $t(190)$ = 3.32, *p* < 0.01), higher controlled motivation predicts a lower learning performance (β = -.78, $t(190)$ = 2.09, *p* < 0.05).

Students' experiences and future preferences regarding WISE

Students' explanations are used to add nuance to the study, enriching it beyond what quantitative analysis can offer. First, it was investigated if students' future preferences (yes – no – only if) were significantly related with student and class-level characteristics. Based on the results of the chi-squared tests, it was found that the students' preferences to be taught by means of WISE in future did not differ between low- and high-achievers within a class ($\chi^2(2, N = 214) = 4.44$, *p* = .11). Yet, a significant relation was found regarding the variables gender ($\chi^2(2, N = 214) = 9.92$, *p* = .007) and academic track ($\chi^2(2, N = 214) = 6.09$, *p* = .048). This means that boys and girls and students from a different track are not equally distributed across a positive, negative or conditional evaluation of using WISE in future.

With regard to gender, as shown in Figure 3 boys were more likely to indicate that they would like to be taught by means of WISE than girls were. Yet, this does not mean that girls are more likely to express reluctance, but they are more critical compared to boys about the conditions under which they would like WISE to be used in future, which are further explained.

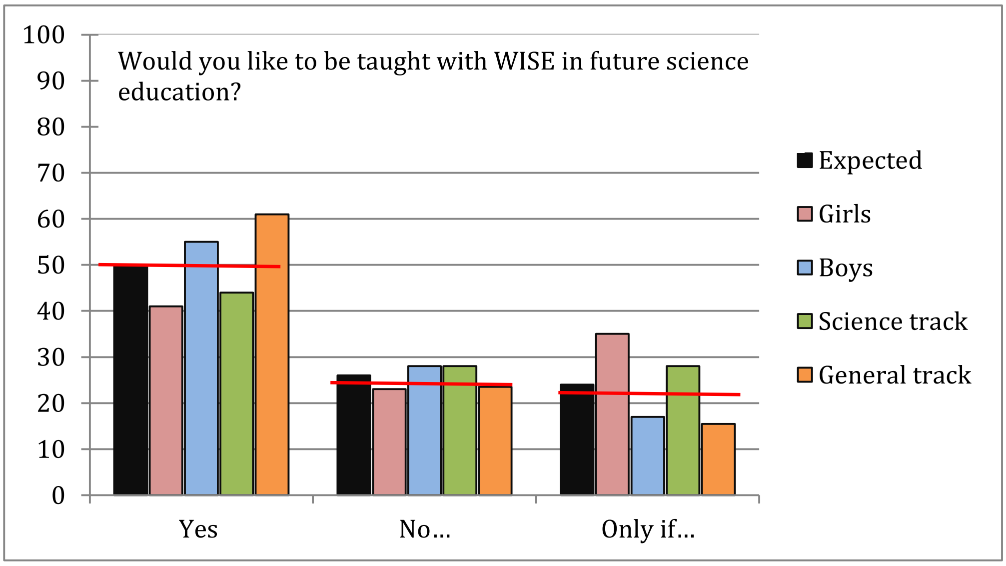

Figure 3. Results of the Pearson Chi-Square test of Independence indicating how the nominal (categorical) variables gender and academic track are distributed across the preferences regarding WISE in future science education.

With regard to students from different tracks, it was found that students from a general track are more positive about using WISE in future science education. Students from a science track are more likely to indicate that they no longer want to be taught in this way, and more students from a science track expressed a conditional desire to use the learning approach in future.

Positive towards WISE in future science education

The reasons why students would like to be taught by means of WISE in the future can be categorized into seven clusters that are ordered in Table 4 based on the frequency that they were mentioned. The top three reasons were the following: 29% of the students mentioned in their own words that it was the active and autonomous learning environment that made them be positive towards WISE in future science education, 26% indicated that they learned more with this teaching approach, and 21% would like it in the future because of the welcome variation in education.

Table 4

Categorization of reasons to be taught with WISE in future science education

Yes, I want to be taught with WISE in future science education, because…	Frequency (Total *N*=101, 50%)
1. Active and autonomous learning e.g. *"Since we all have to formulate answers we certainly pay attention to what we are reading and typing. This is better than just listening to a teacher who explains everything because then you are more easily distracted."* (high-achieving boy from science track)	29% (*N*=29)
2. Higher learning gain e.g. *"In this way, you're really working on the subject, you're going to remember it more easily if you need to explore it by yourself and formulate the answers, much better than "cramming" things you actually do not understand and you will forget almost immediately."* (low-achieving girl from general track)	26% (*N*=26)
3. A welcome variation E.g.: "*I liked being taught in a different way and that we could look for information on the subject by ourselves. It's also nice because you can get information from different sources on the internet, text, video and images."* (high-achieving boy from science track)	21% (*N*=21)
4. Collaborative learning E.g. *"I thought it was fun to work with a partner and do this project together, so you get to know what someone else thinks about it"* (low-achieving boy from general track)	12% (*N*=12)
5. Less boring E.g. *"In this way, we learn in a nicer way, and it is not just pure theory we have to "learn"".* (high-achieving girl from general track)	8% (*N*=8)
6. Use of technology E.g. *"It is an unique way to get information. We live in a digital age and technology should even be used more. On the internet you really find complete, reliable information. You can also achieve more examples than in class."* (low-achieving boy from science track)	7% (*N*=7)
7. Obtaining a critical attitude, learning other competences E.g. *"In this way, we did not only learn something about science, but we also learn to find information and to be critical against this information on the web. By doing it yourself, you better remember it. It's also cool because it's another way of teaching."* (low-achieving girl from science track)	4% (*N*=4)

In a next step, regarding the top three reasons, we investigated by means of the chi-squared test if a significant relation could be revealed with gender, achievement level, and academic track. We only found a significant relation between gender and experiencing WISE as a welcome variation. It was found that girls are more likely than boys to mention this reason ($\chi^2(1, N = 101) = 5.25, p < .05$).

Negative towards WISE in future science education

The reasons why students would not like to be taught by means of WISE in the future could also be categorized into seven clusters that are ordered in Table 5. The most mentioned reason not to choose WISE in future education (36%) is that students indicated that they prefer the teacher in front of the classroom explaining the content, since they indicate learning more or understanding it better in this way. Other reasons less frequently mentioned were that it is too time consuming (13%), the concern about the reliability of the information they found on the web (13%), the high amount of working autonomously (11%), and the difficulty (11%).

Table 5
Categorization of reasons to be reluctant towards using WISE in future science education

No, I do not want to be taught with WISE in future science education, because…	Frequency (Total *N*=55, 26%)
1. Lower learning gain / I prefer the teacher's explanations E.g. *"I understand it much better if the teacher explains the content and we don't have to investigate everything by ourselves."* (high-achieving girl from science track)	36% (*N*=19)
2. To slow / more time consuming E.g. *"It seems to me like a good way to learn, you learn more if you have to search it yourself, but it's much more time consuming. The subject matter should move forward more quickly so I think it's not good."* (high-achieving boy from science track)	13% (*N*=7)
3. Concerns about the reliability of web-based information E.g. *"You never know if the information on the internet is correct, I prefer to listen to someone that know the right information, it is also sometimes difficult to read all the information"* (low-achieving girl from science track)	13% (*N*=7)
4. Too much autonomous work / less relatedness / boring E.g. *"After a while it would bore. You have less social contact with your teacher and classmates and no time for a joke in between. I like more the classical/traditional way of teaching."* (high-achieving boy from science track)	11% (*N*=6)
5. More difficult E.g. *"Sometimes it was not entirely clear to me. The lesson is much easier if the teacher teaches!"* (low-achieving girl from science track)	11% (*N*=6)
6. Technical problems E.g. "*There can always crop up technical problems with the internet, computer, ... And not everyone is good with computers."* (low-achieving boy from general track)	2% (*N*=1)
7. Stress about deadlines E.g. *"If we look up the wrong information, we will get it wrong and it is not nice to meet a deadline each lesson."* (high-achieving boy from science track)	2% (*N*=1)

Based on the chi-squared test, a significant relation could be revealed with the student characteristic achievement level and the most mentioned argumentation, that is, that students felt to experience a lower learning gain and prefer the teacher to explain the content. It was found that high-achieving students in science are more likely than low-achieving students in science to mention this reason ($\chi^2(1, N = 54) = 5.88, p < .05$).

WISE in future science education under certain circumstances

A group of students expressed that they would like to be taught by means of WISE in the future, but only under certain circumstances. These conditions could be categorized into six clusters (see Table 6). Almost half of the students mentioned that they would only like to be taught with WISE in the future if there were a good balance between the teacher explaining the content in a traditional way and autonomously working with the learning environment. Twenty-six percent of the students indicated that they would like it in future, but dealing with a more interesting subject, and 10% indicated that more time needed to be provided.

Table 6
Categorization of reasons to use WISE in future science education under certain circumstances

I only want to be taught with WISE in future science education…	Frequency (Total *N*=50, 24%)
1. In combination with traditional/ classical education led by the teacher E.g. *"If I get enough explanation about what we investigate and if it was not for every day. For me it may happen two times a week. We would do it every day, it would also become bored."* (low-achieving girl from science track)	48% (*N*=24)
2. If other content/ an interesting subject matter is tackled E.g. "If it is about an interesting topic. Because the greenhouse effect does not interest me. It also should be varied with classical education and be occasionally." (Low-achieving girl from general track)	26% (*N*=13)
3. If more time is provided E.g. *"If we get more time and we do not have to complete the assignments at home or in the afternoon time because everyone deserves a little free time"* (low-achieving boy from science track)	10% (*N*=5)
4. If it is more relevant	6 % (*N*=3)
5. If it more clear	6 % (*N*=3)
6. If it is more challenging / difficult	2 % (*N*=1)

Based on the chi-squared test, no significant relations could be revealed between the student or class-level characteristics and the frequency a certain reason was mentioned.

Discussion

The aim of the study was to investigate the motivational effects and challenges when implementing web-based collaborative inquiry in authentic science education. Moreover, it was questioned whether differences could be found across different student groups based on gender, achievement level, and academic track. In this study, motivation is measured based on the self-determination theory (Deci & Ryan, 2000), maintaining that good quality motivation (i.e., high autonomous motivation, low controlled motivation) can be fostered within an environment that facilitates the satisfaction of the basic needs autonomy, competence, and relatedness. Based on the features that web-based collaborative inquiry offer, it was hypothesized that implementing WISE in science classrooms can provide a need-supportive environment, which can foster autonomous motivation and reduce controlled motivation for science learning, and in turn can lead to positive learning outcomes.

Regarding the effects on autonomous motivation, multilevel analyses revealed that although general track students had a significantly lower motivation for science prior to the intervention, these students realized a significant improvement in motivation, whereas science track students' motivation, which was already high, has not significantly changed. Regarding the effects on controlled motivation, it was found that general track students' controlled motivation for science is significantly higher than the motivation for science reported by science track students, yet no significant main effect for academic track was found regarding the change in controlled motivation after the intervention. Based on these results, we can state that the hypothesis of an increased autonomous motivation for science learning is not entirely confirmed, but only holds for general track students. This result is promising given the fact that prior research has indicated that general track students are often disadvantaged in science in the way that they receive less challenging instruction consisting of teacher-centred knowledge transmission (Oakes, 2005). General track students' autonomous motivation prior to the intervention was significantly lower compared to science track students, and their controlled motivation was significantly higher which indicates a lower quality motivation profile. Yet, it seems that this group particularly benefitted from the WISE intervention since they experienced a significant improvement of their autonomous motivation, whereas their controlled motivation did not significantly change. It seems that these students especially appreciated the social, active, and constructive learning process, which is confirmed by the qualitative results: e.g., *"It was fun working together,"* and *"You're really working on the content, you're going to remember it more easily if you need to explore it by yourself and formulate the answers, much better than 'cramming' things you actually do not understand and you will forget almost immediately."* Chi-square tests, moreover, revealed that students from a general track are more positive about using WISE in future science education. Students from a science track, on the other hand, are more likely to indicate that they no longer want to be taught in this way or only under certain circumstances. This result can possibly be explained by the role of misconceptions that students hold since one of the students expressed the following: *"We were forced to think about what we know already and consequently you feel an urge to discover the information we did not know already and the system force you to read more if you are wrong."* Research on conceptual change has demonstrated that when interventions can resolve misconceptions, this also has beneficial effects for students' motivation (Heddy & Sinatra, 2013), so it is conceivable that general track students had more opportunities to correct misconceptions compared to the science track students. Yet, we also have to consider a novelty effect due to the fact that science track students are perhaps more acquainted with inquiry learning. Next to this, we also need to consider the possibility that some students did not perceive learning with WISE as a student-centered approach. Based on students' comments we know, for example, that some students experiences a time pressure which is not need-supportive and will not result in an increase of autonomous motivation.

With regard to gender, boys were more likely to indicate that they would like to be taught by means of web-based collaborative inquiry. This does not mean that girls are more likely to express reluctance, but they are more likely than boys to express the conditions under which they would like WISE to be used in the future. It was revealed that students who were positive towards using WISE in the future (i.e., more students from a general track) mainly mentioned the active and autonomous approach and stressed that this will lead to higher learning gains. Within the group of students who were reluctant towards using WISE in the future (i.e., more students from a science track), most students indicated that they experienced a lower learning gain and that they understand it much better if the teacher explains the content and do not have to investigate everything by themselves. This explanation was significantly mentioned more by high-achievers in science compared to low-achievers in science. These findings are somewhat paradoxical given the fact that teachers often hold the prevalent conception that higher order learning goals in science education and activities in which knowledge needs to be constructed by the learners are only suitable for students with higher cognitive abilities (Zohar & Dori, 2003). In contrast, our study indicates that students with higher cognitive abilities are less likely to appreciate a knowledge integration approach and even prefer a more teacher-centered knowledge transmission approach. This finding can be related to the fact—as described by Linn and Eylon (2011)—that high-achieving students will not hamper from what they call a knowledge absorption approach since they have the skills and ability to connect this new knowledge to their prior knowledge on their own. This also explains that for some students a knowledge integration approach felt more time consuming.

Next to the focus on possible shifts in the quality of motivation after implementing the WISE project, the results of this study confirmed the hypothesis that qualitative motivation, in turn, leads to better learning performance. This result justifies a persisting effort in optimizing student-centered learning approaches fostering motivational processes. In this respect, students' critical feedback is of great value to reveal design guidelines to optimize the implementation of WISE in future science education in light of the satisfaction of the three basic needs (Vansteenkiste et al., 2009). Regarding autonomy support, based on students' feedback, we can assume that most students perceived the intervention as autonomy-supportive, but some of them also stress the amount of autonomous work as a negative point and pointed to having less social contact with the teacher and their classmates. This can be related with the need of relatedness. A lot of students stress that they would only like to be taught with WISE in combination with traditional teacher-centered education. This finding is related with the fact that students need to adjust to a new relationship with the teacher who becomes a facilitator rather than the primary source of information, but also teachers need to adjust to a changing role, which in recent years has become central concern in Computer-Supported Collaborative Learning (CSCL) (Dillenbourg, Järvelä, & Fischer, 2009). Yet further research is needed to get better insight into this specific role of the teacher and the need of orchestrating the learning process across the different social planes, i.e., the individual level, the group level, and the classroom level.

Finally, regarding competence support, although it was found that most students had no operational and technical problems, some students struggled during information problem solving on the web as indicated by the concerns about the reliability of web-based information as one of the reasons to be reluctant towards web-based inquiry, although these evaluation skills could be viewed as an important 21st century skill. This possible pitfall was already indicated by Mayer (2011). In this respect, next to scaffolding domain-specific knowledge, scaffolding the metacognitive skills during web-based inquiry also needs to be included.

Limitations and implications for further research

This intervention study took place in real classrooms and was conducted on a large scale. Researching authentic settings is advantageous because of the high ecological validity; however, there are some drawbacks. Because we were dependent on the willingness of the school board to participate in the research project, our sample was somewhat skewed. Science teachers particularly wanted to participate in the project with their students from the science track because within this track there is more time available for such activities. Yet, this is contradictory, given the finding of this study that this learning approach particularly benefits students from a general track.

Furthermore, due to the fact that science teachers could not spend the time to be trained for teaching the WISE-project according to a set of instructional principles, Master's students in Educational Sciences were trained in advance and acted as the teacher and conducted the questionnaires. Yet, although detailed protocols strived for controllable interventions, still the intervention as intended by the designers and researchers can vary in its enactments by different teachers (in this case Master's students) in their particular contexts. We believe that a more detailed analysis of the teacher's assistance can be added value, for example, by video analysis and finer discourse analysis techniques as conducted by Greiffenhagen (2012). This methodology would provide a better understanding of when and how certain classroom interactions successfully support students' need satisfaction. Autonomy-supportive language characterized by non-directive language is, for example, found to foster greater intrinsic motivation in students (Reeve & Jang, 2006); however, the methodology within this study did not collect this information. Moreover, future research should try to include the real classroom teacher to investigate the motivational and learning effects of teachers classroom-based interventions and additional research should also include the measurement of students' perceived need satisfaction and study the effects of teacher-centered interventions.

We also have to realize that the development of good quality motivation for learning science is an ongoing process (Machina & Gokhale, 2010). Although the present study presents positive and promising results, we need to recognize that in order to maintain a high motivation toward science and to ensure that more young people will be open to participate in science in higher education, an isolated inquiry project addressing a single science topic may not be enough. We need to investigate this learning approach for more extended periods of time and across different science topics. In this respect, professional development to enable teachers to integrate these classroom strategies—collaboration, inquiry, and technology-enhanced learning—in their everyday science teaching is needed.

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6

The effects of teacher-led class interventions during technology-enhanced science inquiry on students' knowledge integration and basic need satisfaction

This chapter is based on:

Raes, A. & Schellens, T. (Submitted). The effects of teacher-led class interventions during technology-enhanced science inquiry on students' knowledge integration and basic need satisfaction. *Computers & Education.*

Chapter 6
The effects of teacher-led class interventions during technology-enhanced science inquiry on students' knowledge integration and basic need satisfaction

Abstract

This study investigated the effects of two differently designed classroom scripts that guided the teacher-led interventions during the courses of the WISE Climate Change project. 168 students from 10 classes were randomly assigned to either the high-structured condition (teacher interventions on group level and on class level) or the low-structured condition (only teacher interventions on group level). Effects were measured on students' knowledge integration and students' need satisfaction. The results did not provide evidence that the high-structured condition leads to higher learning gains, yet it was found that pausing the group work during computer-supported collaborative learning (CSCL) to provide structure and feedback by the teacher at a whole-classroom plenary level significantly lower the feelings of competence frustration. Especially low prior knowledge students expressed higher competence frustration in the low-structured condition. These findings suggest to blend CSCL with teacher-led class interventions to optimize the learning environment.

Introduction

Although computer-supported collaborative inquiry learning (CSCL) is highly promoted for science education, this kind of learning is much more challenging compared to traditional education. Regarding the learner's perspective it can be noted that problem-solving environments rely heavily on students' ownership over their learning and depends on students' self-regulated investigations. Yet, students often lack the regulation skills to plan, monitor and evaluate their inquiry (Azevedo, 2005; Kuiper, Volman, & Terwel, 2009; Raes, Schellens, De Wever, & Vanderhoven, 2012). This means that in inquiry classes, students may encounter challenges when not adequately supported, particularly when they do not have sufficient prior knowledge (Kirschner, Sweller, & Clark, 2006). Where learners lack adequate prior knowledge, naïve assumptions and theories situated in prior experiences and knowledge may limit or fail to adequately inform their inquiry processes. As a result, they tend to develop oversimplified misconceptions that prove highly resilient to change (Hannafin & Land, 2000). In this regard, scaffolding inquiry is crucial to take full advantage of this kind of learning, especially for low-achievers. A huge amount of research has investigated how technology-enhanced scaffolds can support students during CSCL (Azevedo & Hadwin, 2005; Reiser, 2004), yet, the most recent view on scaffolding in technology-rich classrooms is the one of distributed scaffolding (McNeill

& Krajcik, 2009; Puntambekar & Kolodner, 2005; Tabak, 2004) in which scaffolding can be provided by different sources involving the teacher, the peers and the technology (Kim & Hannafin, 2011), on different social levels (through individual, collaborative, and classroom activities (Dillenbourg & Hong 2008) and with different types of scaffolding (e.g. prompting, hinting, debriefing) (Lazonder & Harmsen, 2014).

An important implication of putting forth the notion of distributed scaffolding is that the teacher plays a key role in integrating the different sources of the scaffolding system (Masters & Yelland, 2002; Puntambekar, 2005; Tabak, 2004). However, teachers are not used to and often not well prepared for embedding this innovative and student-centered form of learning in their curriculum and this may result in what Makitalo-Siegl, Kohnle, & Fisher (2011) call a "replaced-by technology" mindset. This is worrying since previous research found that a teacher's passive role was one of the drawbacks mentioned by the students who had experienced a web-based inquiry science project in authentic science education (Raes & Schellens, under review). Next to this it was found that when a teacher is actively involved in the learning process and interacts with groups of students to monitor their (information) problem solving, this particularly benefits girls and learners who lack adequate prior knowledge (Raes et al., 2012). From a self-determination perspective it is moreover stressed that teacher's behavior and the resulting classroom interaction have an important impact on students' motivated learning by meeting or ignoring their basic psychological needs (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). To satisfy the need of autonomy, relatedness and competence the teacher as facilitator of learning needs to make sure to support autonomy, show involvement and provide enough structure.

In line with this movement towards a blended version of teacher- and student-centered procedures that promotes the need of empowerment of teachers as drivers of classroom activities (Dimitriadis, Prieto, & Asensio-Perez, 2013), some researchers have reinforced the teacher's role to implement complex student-oriented, open-ended inquiry processes. In this context, the notion of orchestration has been put forward and developed to refer to the process of flexibly and productively coordinating the help that the teacher needs to follow, on different levels, in CSCL environments (Dillenbourg, Järvelä, & Fischer, 2009; Dillenbourg & Tchounikine, 2007). To assist teachers during their interventions Mäkital-Siegl et al. (2011) for example put forth the use of a classroom script and conclude that appropriate classroom scripts should offer structure and assign the teacher to specify the inquiry learning steps at the whole-classroom plenary level. Teacher-led class interventions provide a space for teachers to elicit students' ideas about the topic being taught, remind students what they studied the last time the class met, and monitor students' developing understanding. Yet, how effective are these teacher-led class interventions during CSCL? How does the design of the teacher-led class interventions contribute to students' learning and their basis need satisfaction? And are differently designed teacher-led interventions more or less effective for different groups of learners? This study investigates these questions by comparing the effects of two differently designed, teacher-led interventions during the course of the Web-based Inquiry Science Environment (WISE) (Slotta &

Linn, 2009) Climate Change project, measuring their effects on students' knowledge integration and students' need satisfaction.

Knowledge Integration and the role of feedback

An important aspect of learning science is that students need to understand the interrelationships between concepts and principles and not study them as isolated facts (Puntambekar, Stylianou, & Goldstein, 2007). So building deep conceptual understanding does not occur by simply transmitting knowledge, but students need to make connections themselves, a process that can be fostered by instructional materials or an inquiry learning environment as WISE and teacher facilitation. The knowledge integration perspective on science learning is the driving force behind the design of WISE and can be defined as the process of incorporating new information into a body of existing knowledge by guiding students to engage in inquiry (Linn & Eylon, 2011). According to the knowledge integration approach, inquiry can be defined as the intentional process of diagnosing problems, generating hypotheses, critiquing experiments, planning investigations, searching for information, constructing explanations, debating with peers, and forming coherent arguments. Well-designed science instruction plays an important role in enabling students to connect science ideas for deeper understanding so that they can apply them in different contexts and teacher-led discussions are an important aspect of such instruction (Linn, Eylon, & Davis, 2004). Teacher-led interventions can provide a rich opportunity for students and teachers to monitor understanding, sort out ideas about difficult concepts, and revisit and refine their reasoning. Puntambekar et al. (2007) in this context stressed that it is important that a teacher helps to provide opportunities for what Tabak and Reiser (1997) described as making students' individual knowledge "public", providing a shared knowledge base for all the students. This is especially important in a classroom where groups of students with varying levels of prior knowledge are learning together, leading to a common forum for students to share what they already know. This is consistent with the finding of Black and William (1998) who revealed that the use of formative assessment techniques is one of the most powerful ways to increase student learning gains, particularly in low-achieving students. More specific, Shute (2008) defines formative feedback as information communicated to the learner that is intended to modify his or her thinking or behavior to improve learning and identifies two main types of information that may be presented during a formative feedback moment. First, verification gives learners information on whether the answer is correct or not; second, elaboration gives cues to guide learners toward a correct answer. The formative assessments are already systematically build into the learning environments in line with the instructional pattern of eliciting ideas, add new ideas, distinguish among ideas, and reflect and integrate ideas. An example of an activity following this instructional pattern is presented in Figure 1.

What do you think? →	Discovering energy transfer →	What do you think now?
What kind of energy from the Sun reaches the Earth? - Light - Heat - Both light and heat	Through different activities in which students formulate their prediction based on several informative steps. Subsequently students can test their prediction by means of the simulation (powered by Netlogo) displayed below.	Students are again asked to answer the same question, that is "What kind of energy from the Sun reaches the Earth" and if they are wrong, they are prompted to go back to previous steps and more particularly to go back to the model and watch more sunrays.

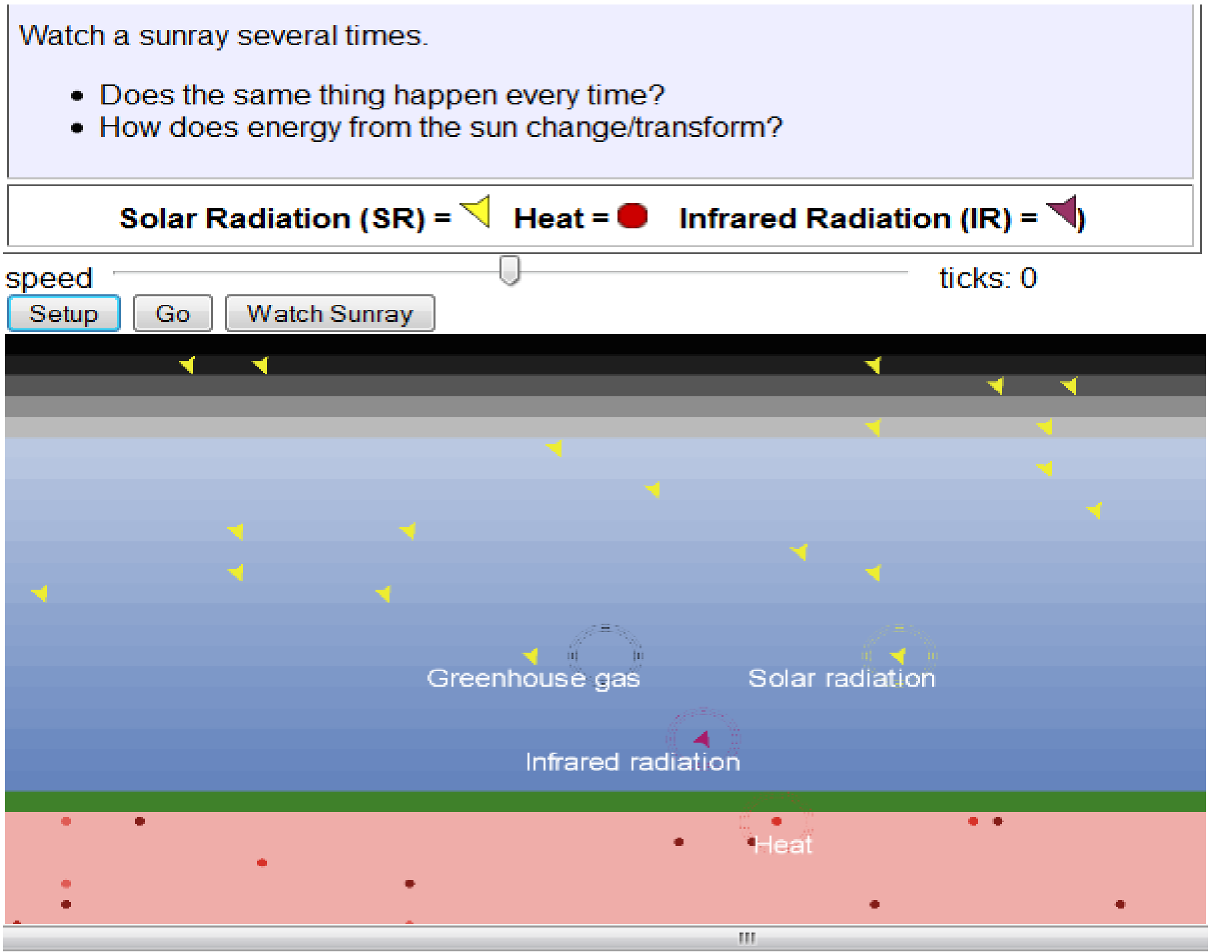

Figure 1. Example of an activity following the knowledge integration instructional pattern. The screenshot is taken from the project "What Impacts Global Climate Change" available on http://wise.berkeley.edu. The simulation used in this project is powered by the modeling environment NetLogo.

Moreover, as shown in Figure 2, the WISE environment equips also teachers with unique tools that manages formative assessment and feedback interventions. There is the Progress Monitor to view student work online in real-time and the Pause Screen feature to pause work on student computers simultaneously. In addition, teachers can "flag" and display artifacts of students' work that illustrate students' ideas about a challenging concept as students progress through the curriculum unit. Yet, although educational technology are more and more designed to assist teachers in their classroom management, research focusing on interventions using these tools are still limited and demanding (Dillenbourg, 2013).

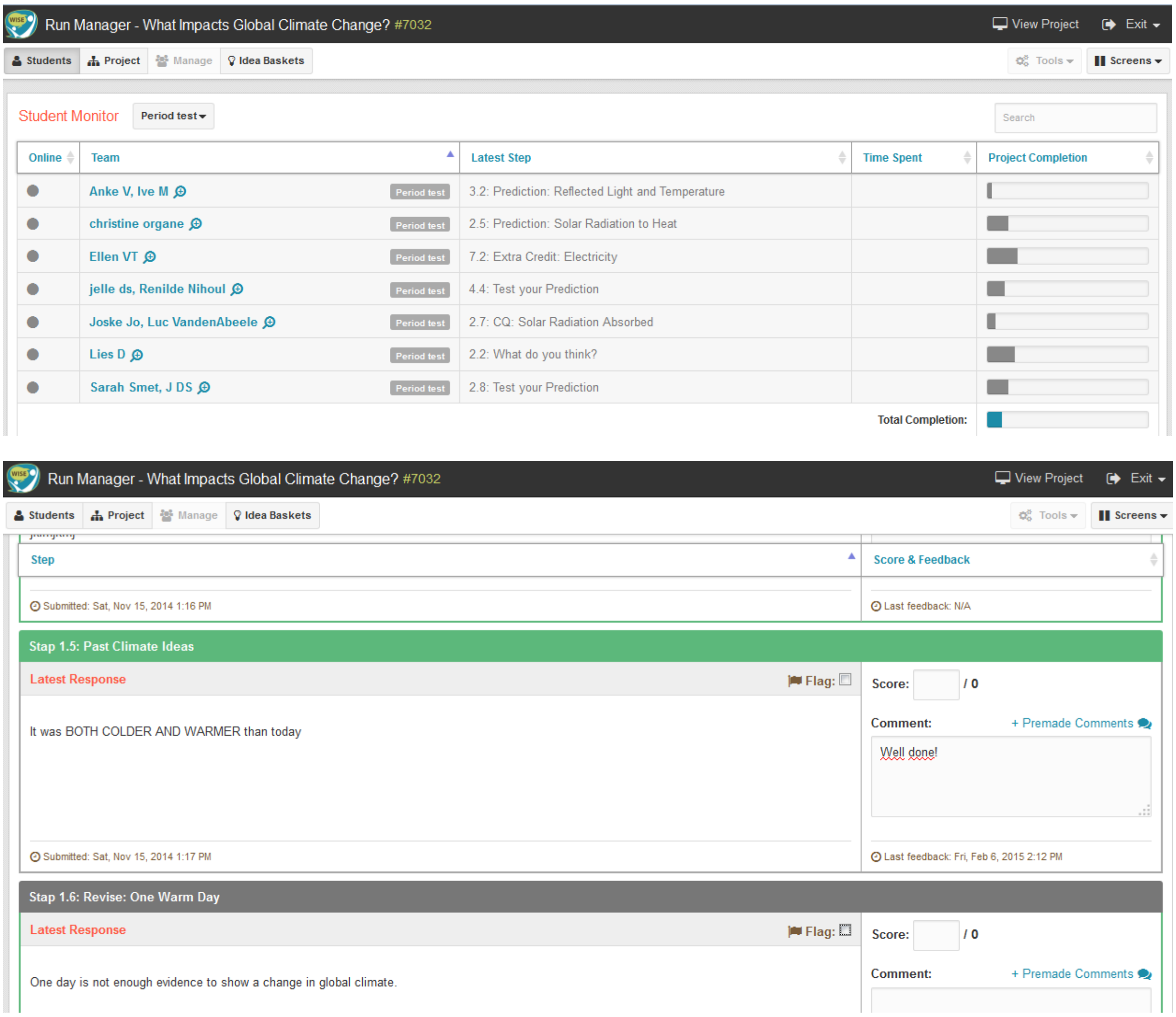

Figure 2. Screenshots from the WISE Teacher tools: online progress monitor, and assessment and feedback tool.

Basic need satisfaction and the role of providing structure

The Self-Determination Theory (SDT) (Deci & Ryan, 1985) indicates that the social context of a learning environment can influence the motivation students experience, assuming that the source of motivation is internal (i.e. autonomous versus controlled) and that when the social surround satisfies students' basic psychological needs, motivation will flourish. Moreover, it has been shown that an autonomous, relative to a controlled, regulation of study activities is associated with various positive learning outcomes (Reeve, Deci, & Ryan, 2004). Hence the question raised based on this theory is what can be done to create a learning context which meets students' psychological needs?"

It is stressed that teachers can have an impact on students' motivation for learning by meeting or ignoring their basic psychological needs (Vansteenkiste et al., 2009). According to this perspective, these needs include the *need for autonomy, the need for competence,* and *the need to be related to other people*. Based on these needs, dimensions of teacher behavior which should foster their fulfillment can be derived. First, students' experience of *autonomy* in learning is promoted when teachers offer students choice regarding the learning activities and provide connections between school activities and students' interests, which we term *autonomy support* (Deci, Eghrari, Patrick, & Leone, 1994). Second, students' need for *competence* is fostered when teachers provide optimal challenging tasks, encouragement after failure, and adequate help. Moreover, to fulfill students' competence satisfaction and counter students' competence frustration teachers should communicate clear guidelines and expectations with respect to the task that needs to be accomplished, all of which are subsumed under the construct *structure* (Reeve, 2002). Finally, to meet the third basic need of *relatedness* it is important for students to experience a sense of closeness and friendship with one's student peers and teachers should take time for and express enjoyment in their interactions with students, referred to as *involvement* (Vansteenkiste et al., 2009).

Given the characteristics of the web-based collaborative inquiry environment (Linn & Eylon, 2011; Slotta & Linn, 2009), a previous study (Raes & Schellens, Under Review) hypothesized that applying this learning approach can be assumed as need-supportive teaching which can foster autonomous motivation for science learning and in turn can lead to positive learning outcomes. Although the study confirmed the hypothesis that higher autonomous motivation leads to better learning performance, students' critical feedback revealed that students' basic needs during web-based collaborative learning were not fully satisfied, and this was particularly true regarding the need for competence. It was found that most students perceived the intervention as autonomy-supportive, but some of them also stressed the amount of autonomous work as a negative point and pointed to have less social contact with the teacher and their classmates which is related to an unsatisfying need of relatedness. A lot of students stressed that they would only like to be taught with WISE in future in combination with traditional teacher-centered education. The need for the teacher's involvement was also mentioned as a condition to feel competent since students often struggled during information problem solving on the web. They stated that they often felt lost and were scared to learn the wrong things which was for several student a reason to be reluctant towards web-based inquiry in future science education. The teacher should find the optimal balance between supporting students' autonomy during inquiry learning on the one hand, but make sure that students do not get overwhelmed by the complexity or the frustration that can sometimes arise in doing science inquiry (Tabak & Reiser, 2014; Sierens et al, 2009).

Scripting web-based collaborative learning

As became clear in the previous paragraphs, in technology-enhanced inquiry learning students need to adjust to a new relationship with the teacher who becomes a facilitator rather than the primary source of information (Blumenfeld, Kempler, & Krajcik, 2006), but also teachers need to adjust to a changing role which in recent years has become a central concern in CSCL (Dillenbourg et al., 2009). Yet, more research is needed to get insight in this specific role of the teacher and the need of orchestrating the learning process across the different social levels, that is the individual level, the group level and the classroom level. In this context, we can refer to the term *classroom script* or *macro-script* to indicate how students as well as the teacher act in specific classroom situations (Dillenbourg & Hong, 2008; Seidel & Prenzel, 2006). Although there is a lot of research about the effect of micro-scripts providing students with detailed guidance on specific activities which they are expected to adopt and progressively internalize (De Wever, Schellens, Van Keer, & Valcke, 2008; Weinberger, Stegmann, & Fischer, 2010), so far the role of the teacher in script-assisted teaching is lacking as indicated by several authors (Makitalo-Siegl et al., 2011; Onrubia & Engel, 2012). The limited papers report that the teacher plays an important role (e.g. Greiffenhagen, 2012). The study of Mäkital-Siegl et al. (2011) examined the influence of a high- compared to a low-structured classroom script leading the teacher's behavior during CSCL on help-seeking processes and learning gains. They found that students in the high-structured condition sought less help but leant more and concluded that appropriate classroom scripts should offer stucture and assign the teacher to specify the inquiry learning steps at the whole-classroom plenary level. Based on the assumption that different groups of learners might benefit from different instructional approaches (conceptualized as Aptitude-Treatment-Interaction (Cronbach & Snow, 1977)), it was moreover put forth that highly structured instructional environments will probably be more successful with students of lower ability and that low structure environments on the other hand may result in better learning for high ability students. However, this study did not test this interaction hypothesis, but recommended this for follow-up research. To the best of our knowledge, this research is still lacking, as well as the research on the effects of differentially designed classroom scripts on students' need satisfaction.

Research objectives and hypotheses

This study build on and tries to fill the gaps in existing research presented above by answering the following research questions:

1. Does providing teacher-led class interventions during web-based collaborative inquiry leads to better knowledge integration, higher competence satisfaction and lower competence frustration?
2. Can we identify aptitude-by-treatment interactions based on the student characteristics gender and achievement level?

This study investigates these questions by comparing the effects of two differently designed classroom scripts (in line with the study of Mäkital-Siegl et al. 2011: high-structured vs. low-structured) that guided the teacher-led interventions during the course of the WISE Climate Change project and measuring their effects on students' knowledge integration and students' need satisfaction. Based on the theoretical framework, it is hypothesized that the high-structured condition will lead to higher knowledge integration and a better need satisfaction and will particularly benefit student with low prior knowledge.

Method

Study participants and design

As depicted in Figure 3, participants in this study were 168 students from 10 classes (grade 9 and 10) who implemented the WISE project during four consecutive course sessions. Students were between 14 and 17 years old (M = 15.55, SD = .54) and 84 of them were boys (65.1%), 45 were girls (34.9%). As depicted in Figure 3, the classes were divided ad random over two conditions: (1) The low-structured classroom script condition (5 classes, N = 81) in which the teacher-led class interventions were limited to a practical oriented introduction in every session; during group work the teacher "made rounds" and was available for help; (2) The high-structured classroom script condition (5 classes, N = 87) in which the teacher interacted at the whole-classroom plenary level in every session, next to "making rounds" during group work. Teachers' interventions were controlled by means of a predefined protocol that indicated how and with regard to which project activities a classroom discussion should be organized; the protocol is further explained in section 6.2.2. By means of a pre- and post-test quasi-experimental design, effects were measured on students' knowledge integration and students' need satisfaction (see section 6.4). Unfortunately, there were 21 students who were absent during the course session in which pre- and/or post-test had been administered, consequently these students were missing when comparing the pre-and post-tests.

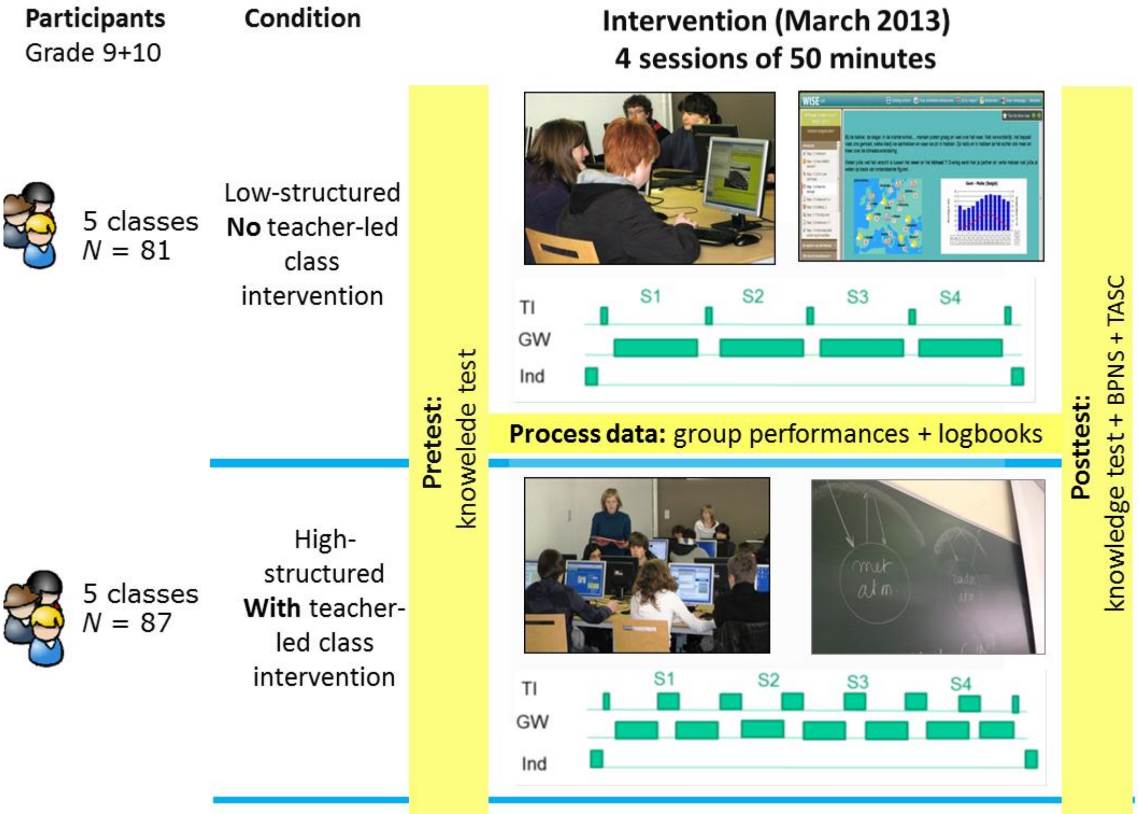

Figure 3. Design and procedure of the quasi-experimental study including 4 course sessions (S1-S4)). The three lines in the figure stand for the three social levels, that is the individual level (Ind), the group level on which students did group work (GW) and the classroom level on which the teacher interventions (TI) took place.

Inquiry learning environment and the classroom scripts

The Web-based Inquiry Science Environment (WISE)

Consistent with previous studies (Raes, Schellens, & De Wever, 2014; Raes et al., 2012) global warming and climate change was chosen as the topic under investigation during the web-based inquiry project that spanned four regular science lessons. The Web-Based Inquiry Science Environment (WISE) (Slotta & Linn, 2009) had been used to design and implement the project. WISE is developed to provide a solid online platform that allows teachers to adopt new forms of inquiry-based instruction. For students, on the other hand, it is a powerful learning environment where they examine in dyads real world evidence from the web and analyze current scientific controversies. Based on the *knowledge integration* approach previously described, Slotta and Linn (2009) have built a design framework for science curriculum projects consisting of four design principles (i.e. "Make science accessible - Make thinking visible - Help students learn from others - Promote autonomy") and the instructional pattern (i.e. "Elicit ideas – Add new ideas – Distinguish among ideas – Reflect on and integrate ideas").

During the project, students worked in the same dyads during the whole intervention and they navigated through the sequence of inquiry activities using the inquiry map in the WISE environment. They were asked to write their answers down in input boxes embedded in the web-based project. Technology-enhanced scaffolds were embedded in the project by means of question prompts, hints and feedback during self-assessment exercises and students were prompted throughout the project to discuss the topic with their partner and collaboratively respond to the questions. Yet, it was hypothesized that next to technology-enhanced scaffolding, scaffolding through peer interaction, and teacher-enhanced scaffolding during group work, teacher's intervention on class level are necessary to improve the conditions for learning and satisfy students' needs.

Implementing the high- and low structured classroom script

In this study we focus on the use of two differentially designed macro-scripts which we conceptualize as classroom scripts coordinating the teacher's behavior on the different levels (Dillenbourg & Hong, 2008). In line with Kollar, Wecker, Langer, and Fischer (2011) and as shown in Figure 3 both classroom scripts could be graphically represented on three parallel lines which represent the individual, the group and the classroom/plenary level. In both conditions, the activities at the individual level were limited to the accomplishment of the pre- and post-test. Yet, the time spent at the group and classroom level differed between the high- and low-structured condition.

In the *low-structured script condition* students predominately worked in groups by navigating through WISE. Teacher intervention was limited to giving a practical oriented introduction in every session at a plenary level. However, the teacher was available for help on students' demand.

Following the *high-structured classroom script*, the teacher interacted at the whole-classroom level not only to give practical guidelines, but also to benefit learning and need satisfaction. Based on the design guidelines of the knowledge integration framework, each session commenced at the plenary level with the teacher providing clear instructions on what was expected and *uncovering students' initial ideas* about the topic under investigation. In the first session for example an introductory movie about global warming has been projected on screen in front of the classroom and subsequently the teacher led a class discussion aiming to activate prior knowledge about the problem of climate change. Next, the teacher asked questions about how researchers would act to solve their research questions and *new ideas could be added*. The class discussion ended with summarizing the inquiry steps researchers take while solving a problem. Subsequently, student dyads fulfilled activity 1 and activity 2 on WISE. Each session ended with a *reflection and elaboration on students' collected ideas* regarding for example the common misconception about light, heat, and the sun organized by the teacher at the plenary level. Based on the progress monitor within WISE, the teacher could select one or two answers to show anonymously in front of the whole class as starting point for the class discussion.

Instructions for teachers and manipulation check

Teacher participation in the intervention was voluntary and teachers were reached through professional development sessions about innovative practices in science education and through a call for participation which had been sent to different school boards. Since it has been found that in a curriculum unit consisting of different activities, teachers themselves need to understand the cycle of activities to effectively help students understand how the activities are related to each other (Puntambekar et al., 2007), volunteering teachers were invited for a one day workshop two months preceding the implementation. The workshop aimed to get teachers acquainted with the learning environment WISE, the specific Global Warming and Climate Change project and the knowledge integration framework. Subsequently, two weeks in advance of the intervention, the participating teachers got the predefined protocol/classroom script which they were asked to follow.

To warrant - as far as possible- for controlled circumstances, manipulation checks were included to assess whether the conditions were successfully put into practice. First, at least two Master's students Educational Technology were present in each session to observe and assist the real classroom teachers if needed. The observations resulted in one logbook per class per session and could be used to check if the implementation of the classroom scripts in both condition were accomplished appropriately. Next to this, one scale, that is provision of structure, of the Teacher as Social Context Questionnaire (TASC) (Belmont, Skinner, Wellborn, & Connell, 1988) was used as manipulation check. After the intervention, by means of the post-test, all students were asked to rate six items about how they experienced the teacher's provision of structure on a 7-point Likert scale (e.g. *"The teacher checks if I understand/ master the exercise before continuing",* Cronbach's Alpha was 0.89).

Measurements

Students' Knowledge Integration

As the curriculum project was designed based on the knowledge integration framework, which aims at an integrated and coherent understanding of science, the outcome measures evaluated the extent to which students are able to link and connect ideas using evidence instead of merely recalling isolated ideas. The pre- and post-knowledge test to investigate the learning effect on knowledge integration consisted of five assessment items scored on a rubric from 0-4 which rewards both accurate and connected ideas. This rubric is an adapted version of the knowledge integration rubric created by the Technology-Enhanced Learning in Science Community (TELS, 2010) and can be find in Appendix A together with an example of the assessment items. The scores of the five assessment items were summed up to form a score for individual knowledge integration (min. 0 - max. 20).

Next to the individual learning outcomes, students' group performance during the project was evaluated. In 25 steps throughout the project, student dyads were asked to write their answer and/or reflection down on the platform. All these notes were scored using a 0-1-2 rubric. Since not all student groups worked on the same pace, some activities were marked as "extra" (i.e. not necessary to successfully complete the post-test) and could be completed by groups who worked faster than others. So, if student groups skipped some steps because they did not have the time to complete this step, this was not marked as a zero, but these steps were left out to calculate the final group score out of 50.

All students' individual and group work were coded by two independent raters who received a training for applying the rubrics. Krippendorff's alpha reliability statistics were calculated to judge the inter-rater reliability of the coded variables (Hayes & Krippendorff, 2007). A Kalpha of 0.80 is often brought forward as the norm for a good reliability, with a minimum of 0.60. The Kalpha estimations based on the coding of the two independent raters are shown in Appendix B and we can conclude that the Krippendorff's alpha values regarding the coded variables were all acceptable.

Students' Basic Need Satisfaction

To measure students' need satisfaction regarding the intervention, the Basic Psychological Needs Scale (Chen et al., Manuscript accepted for publication) was conducted in the post-test. Regarding the design and focus of this study we will only present the results regarding the satisfaction and frustration of students' competence (e.g. respectively "*I felt that I could succeed in difficult tasks during the project*" and "*I had serious doubt whether I could successfully complete the project*" which were rated on a seven-point Likert scale from 1 totally disagree to 7 totally agree). Each scale was measured by four items of which the Cronbach's Alphas were satisfactory, 0.80 for competence satisfaction and 0.81 for competence frustration.

Statistical analysis

As the students worked together in small groups and these groups originated from existing classes, the problem under investigation has a clear hierarchical structure. In this respect, multilevel modeling is suggested as an alternative and adequate statistical approach in CSCL research (Cress, 2008; De Wever, Van Keer, Schellens, & Valcke, 2007) as it enables the testing of main effects and interaction effects of predictor variables on different levels. The software MLwiN 2.23 for multilevel analysis was used to analyze the hierarchical data (Hox, 1994). In a first step, unconditional multilevel null models were built for the dependent variables without predictor variables to check the variances at the different levels. By means of the intraclass correlation (ICC), which reveals the correlation of the observations (cases) within each cluster on the different levels, the null model answers the question of whether the outcome measures vary among students, across dyads and across classes. The second step concerned the input of the condition variable and in the third step students' characteristics, that is gender (female versus male students) and achievement level (high- versus low-achiever based on the mean (5.5) split of students' prior knowledge) were added to model as fixed effects and in interaction with condition.

Results

Manipulation check

Based on the analysis of the logbooks, two classes had to be excluded from the dataset to improve reliability. In one class, due to practical circumstances, the post-test had been conducted only three weeks after the end of the intervention with a holiday in between compared to the other classes in which the test administration was included in the four sessions. This class consisted of 21 students and belonged to the low-structured condition. Next to this, it has been observed that in one class of 18 students belonging to the high-structured condition, the teacher who had followed the training workshop had totally neglected the protocol and did not provide the teacher-led discussions.

Second, students' experienced provision of structure by the teacher measured by the TASC questionnaire was analyzed by means of multilevel analysis. A three-level model was built, that is individuals within groups within classes. As displayed in Table 1 based on the fixed part of the null model, we can state that across all students, the average (*SE*) experienced provision of structure was 5.02 (0.10) on a 7-point Likert scale which indicates that students on average "rather agree" about the provided structure by the teacher during the web-based inquiry project. Moreover, the null model partitions the variance into between classes, within class - between groups, and within group - between students components. Based on the random part results, we can state that most of the variance is situated at the student level (ICC = 59.2%) and the group level (ICC = 38.4%). Only 2.4% variance is situated at the class level. In the next step the variable condition has been added to the model with the low-structured condition as reference category. Based on the results shown in Table 1, as expected by the manipulation, students in the high-structured condition experienced a higher provision of structure compared to the low-structured condition (χ^2 = 4.29, *df* = 1, *p* = .04). A nested hypothesis test (chi-square goodness of fit test) checked whether adding this variable was significant and as indicated in the table this resulted in a significant model improvement.

Table 1

Multilevel parameter estimates for the three-level analyses of students' reported provision of structure by the teacher (TASC, 7-point Likert scale, 1 totally disagree, 7 totally agree)

Parameter	Null Model	Model with condition
Fixed part		
Intercept β_0	5.02 (0.10)	4.81 (0.13)
High-structured condition β_1		0.37* (0.18)
Random part		
(L3) Class variance	0.02 (0.04)	0.00 (0.00)
(L2) Group variance	0.33* (0.09)	0.32* (0.08)
(L1) Student variance	0.51* (0.05)	0.51* (0.05)
Model fit		
-2*log likelihood	602.20	598.30
χ^2 (*df* = 1)		3.9
p		0.04
Tot variance	0.86	0.83
ICC Class	2,4%	0%
ICC Group	38.4%*	39%*
ICC Student	59.2%*	61%*

Note. Standard errors are in parentheses. * indicates *p* < .05

Knowledge integration in differently structured classroom script conditions

Effect of differently structured classroom script conditions (RQ1)

To investigate the impact of the teacher-led class interventions on students' knowledge integration, multilevel analyses were conducted on students' group performances and on students' individual learning outcomes. Regarding students' group performances as indicated in Table 2, based on the fixed part of the null model, we can state that across all students, the average (*SE*) group performance was 34.63 (1.46) out of 50 and the variance is partitioned in 47.32% on group level and 52.68% on class level. After adding condition to the model with the low-structured condition as reference category, no significant difference was found between both conditions regarding students' group performance scores.

Table 2

Multilevel parameter estimates for the two-level analyses of students' group performances (out of 50)

Parameter	Null Model	Model with condition
Fixed part		
Intercept β_0	34.63 (1.46)	32.93 (1.36)
High-structured condition β_1		3.40 (2.68)
Random part		
(L2) Class variance	16.63 (8.57)	13.79 (7.16)
(L1) Group variance	14.94* (1.36)	14.94* (1.36)
Model fit		
-2*log likelihood	1413.80	1412.32
χ^2 (df = 1)		1.00
p		0.32
Tot variance	31.57	28.73
ICC Class	52.68%	47.90%
ICC Group	47.32%*	52.10%*

Note. Standard errors are in parentheses. * indicates $p < .05$

Regarding students' individual learning outcomes, owing to the pre- and post-test design used in this study, the data analysis encompasses repeated measures on individuals over time. The test time was thus added as a dummy variable (0 = pre-test or T0; 1 = post-test or T1) and lowest level in the model. Consequently, a four-level structure arose: both test times (level 1) are clustered within students (level 2), which are nested within dyads (level 3), which in turn are nested within classrooms (level 4). As we used a repeated-measures approach, our conceptual unconditional null model (presented in Table 3) predicts the overall knowledge score on the pre-test across all students, dyads and classes (= the intercept, i.e. 5.10 out of 20) as well as students' overall significant learning gain (slope β_1, i.e. 3.77) with regard to knowledge integration. This model also gives rise to two residuals per level as shown in the random part of the model, one for pre-test, and one for learning gain. The total variance of the pre-test scores is 6.8 and after calculation of the ICC, we can state that 48 % of total pre-test variance lies at the class level, the proportion of variance due to differences between dyads is 4.5%, and 47.5% of the total variance lies at the student level. With respect to the variance in learning gain, the total variance of 8.96 consists of 31% between-class variance, 9.7 % between-dyad variance, and 59.3% between-student variance. In the next steps the variable condition and the student characteristics were added to the model. However, when adding the student characteristics, the model did not converge due to the complexity of the model and the sparse data structure (Rasbash, Charlton, Jones, & Pillinger, 2009). Consequently, it was decided to remove the non-significant group level and run the 3-level model (see Table 3). Results of the three-level model with condition indicate that students in both conditions did not significantly differ with respect to their prior knowledge (i.e. their scores on the pre-test) (χ^2 = 0.25, df = 1, p = .62), but a significant difference was found regarding the learning gain students achieved in both conditions (χ^2 = 5.23, df = 1, p = .02). Students in the high-structured condition achieved a significantly higher learning gain compared to students in the low-structured condition.

Table 3

Multilevel parameter estimates for the four- and three-level analyses of students' knowledge integration, the model indicates both the pre-test scores and the learning gains from pre- to post-test students achieved

Parameter	Null Model (4-level)	Null Model (3-level)	Model with condition (RQ 1)	Full model (RQ 2)
Fixed part				
Intercept	5.10 (0.68)	5.09 (0.67)	4.75 (0.93)	2.80 (0.59)
Learning gain	3.77* (0.99)	3.77* (0.64)	2.60* (0.74)	3.76* (1.14)
High-struc. Condition (HSC)			0.66 (1.31)	1.42 (0.79)
HSC*Learning gain			2.32* (1.02)	2.06 (1.76)
Boy				0.29 (0.58)
High				3.55* (0.65)
Boy*High				0.43 (0.73)
HSC*High				-0.37 (0.83)
HSC*Boy				-0.74 (0.75)
HSC*Boy*High				-0.21 (0.97)
High*Learning gain				-1.47 (1.65)
Boy*Learning gain				0.21 (1.43)
Boy*High*Learning gain				-1.64 (1.69)
HSC*High*Learning gain				0.17 (1.92)
HSC*Boy*Learning gain				-0.07 (1.67)
HSC*Boy*High*Learning gain				0.21 (2.08)
Random part				
Level 4 - Class				
Intercept/intercept (σ^2_{f0})	3.27 (1.78)	3.31 (1.79)	3.20 (1.73)	0.48 (0.29)
Learning gain/learning gain (σ^2_{f1})	2.77 (1.68)	2.81 (1.66)	1.54 (1.02)	1.99 (1.23)
Learning gain/intercept (σ^2_{f10})	0.23 (1.22)	0.31 (1.22)	-0.02 (0.94)	0.42 (0.44)
Level 3 - Group				
Intercept/intercept (σ^2_{v0})	0.31 (0.47)	/	/	/
Learning gain/learning gain (σ^2_{v1})	0.87 (0.89)	/	/	/
Learning gain/intercept (σ^2_{v10})	0.22 (0.49)	/	/	/
Level 2 - Student				
Intercept/intercept (σ^2_{u0})	3.22* (0.59)	3.50* (0.47)	3.51* (0.47)	1.46* (0.20)
Learning gain/learning gain (σ^2_{u1})	5.32* (1.03)	6.16* (0.87)	6.13* (0.86)	5.33* (0.75)
Learning gain/intercept (σ^2_{u10})	-1.76* (0.60)	-1.58* (0.49)	-1.57* (0.49)	-0.27 (0.28)
Level 1 – Test time				
Intercept/intercept (σ^2_{e0})	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Model fit				
-2*log likelihood (Deviance)	1034.25	1038.77	1034.37	901.89
χ^2			4.4	132.48
df			2	12
p			0.11	0.00
Tot variance (pre-test / gain)	6.8 / 8.96	6.61 / 8.97	6.71 / 7.67	1.94 / 7.32
ICC Class	48% / 31%	47% / 31%	48% / 20%	25% / 27%
ICC Group	4.5% / 9.7%	/	/	/
ICC Student	47.5%/ 59.3%	53% / 69%	52% / 80%	75% / 73%

Note. Standard errors are in parentheses. * $p<.05$

Differential effects between students (RQ2)

To investigate whether we can identify differentiated effects based on gender and achievement level these predictors were included in the model as fixed main and fixed interaction effects. The reference group to which the other groups of students are compared is, in this case, a girl who is a low-achiever in the low-structured condition. As shown in the full model depicted in Table 3, the effect of condition did not remain after controlling for student characteristics, although adding these variables to the model resulted in a better model fit (χ^2 = 132.48, df = 12, p < .01). Based on this full model, Figure 4 was build which depicts the adjusted predicted means for the different groups of students in order to visually represent the results of this full model. Although learning gains were for all groups higher in the high-structured condition compared to the low-structured condition, these differences did not prove to be significant.

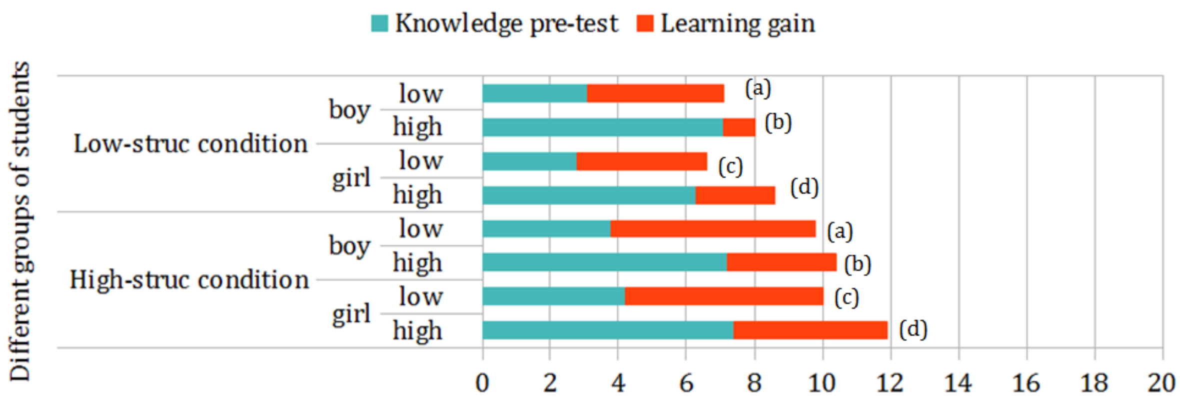

Figure 4. Graphical representation of the adjusted predicted means of knowledge pre-test scores and learning gains of the individual students. (a), (b), (c), and (d) indicate that the difference in learning gains of these groups has been compared and resulted in following statistics: (a) χ^2 = 2,16, df = 1, p = 0.14; (b): χ^2 = 3.19, df = 1, p = 0.07; (c): χ^2 = 1.36, df = 1, p = 0.24; (d) χ^2 = 2,24, df = 1, p = 0.13.

Basic need satisfaction

Effect of differently structured classroom script conditions (RQ1)

Both students' competence satisfaction and students' competence frustration was modeled by means of multilevel modeling, see respectively Table 4 and Table 5 for the modeling representation. Regarding students' competence satisfaction during the WISE-project, the overall score on the post-test across all students was 4.86 on a 7-point Likert scale. The random part indicates that the variance is particularly at the student (ICC = 53.2%) and group level (ICC = 35.9%). After adding the variable condition to the model with the low-structured condition as reference category, it was found that students in the high-structured condition reported a higher competence satisfaction compared to students in the low-structured condition (χ^2 = 4.20, df = 1, p = .04). Similar results were found regarding students' competence frustration, yet in the other direction. The overall score on the post-test across all students was 2.67 on a 7-point Likert scale and the variance is also particularly at the student (ICC = 57%) and group level (ICC = 41.9%). After adding the variable condition to the model with the low-structured condition as reference category, it was found that students in the high-structured condition reported a significantly lower competence frustration compared to students in the low-structured condition (χ^2 = 7.80, df = 1, p < .01).

Table 4

Multilevel parameter estimates for the three-level analyses of students' reported Competence Satisfaction (BPNS, 7-point Likert scale, 1 totally disagree, 7 totally agree)

Parameter	Null Model	Model with condition (RQ 1)	Full model (RQ2)
Fixed part			
Intercept β_0	4.86 (0.12)	4.65 (0.15)	4.56 (0.35)
High-struc condition (HSC)		0.41* (0.20)	0.19 (0.45)
Boy			0.29 (0.29)
High-achiev			-0.18 (0.34)
Boy*HSC			0.16 (0.35)
High-achiev*HSC			0.16 (0.39)
Boy*High-achiev			-0.47 (0.36)
Boy*High-achiev*HSC			0.48 (0.43)
Random part			
(L3) Class variance	0.07 (0.06)	0.03 (0.04)	0.19 (0.13)
(L2) Group variance	0.23* (0.06)	0.23* (0.06)	0.35* (0.08)
(L1) Student variance	0.34* (0.04)	0.34* (0.04)	0.23* (0.03)
Model fit			
-2*log likelihood	511.60	508.06	437.44
χ^2		3.54	70.62
df		1	6
p		0.06	< 0.001
Tot variance	0.64	0.60	0.77
ICC Class	10.9%	5%	24%
ICC Group	35.9%	38%	45%
ICC Student	53.2%	57%	31%

Note. Standard errors are in parentheses. * indicates p < .05

Table 5

Multilevel parameter estimates for the three-level analyses of students' reported Competence Frustration (BPNS, 7-point Likert scale, 1 totally disagree, 7 totally agree)

Parameter	Null Model	Model with condition (RQ 1)	Full model (RQ2)
Fixed part			
Intercept β_0	2.67 (0.10)	2.96 (0.14)	3.81 (0.32)
High-struc condition (HSC)		-0.51* (0.18)	-0.87* (0.38)
Boy			-1.11* (0.35)
High-achiev			-0.43 (0.39)
Boy*HSC			0.27 (0.43)
High-achiev*HSC			0.45 (0.46)
Boy*High-achiev			0.36 (0.44)
Boy*High-achiev*HSC			-0.21 (0.54)
Random part			
(L3) Class variance	0.01 (0.04)	0.00 (0.00)	0.00 (0.00)
(L2) Group variance	0.39* (0.10)	0.34* (0.08)	0.35* (0.09)
(L1) Student variance	0.53* (0.05)	0.53* (0.06)	0.43* (0.05)
Model fit			
-2*log likelihood	615.00	607.80	537.24
χ^2		7.2	70.56
df		1	6
p		0.01	< 0.001
Tot variance	0.93	0.87	0.78
ICC Class	1,1%	0%	0%
ICC Group	41.9%	39%	45%
ICC Student	57%	61%	55%

Note. Standard errors are in parentheses. * indicates $p < .05$

Differential effects between students (RQ2)

To investigate whether we can identify differentiated effects based on gender and achievement level these predictors were included in the model as fixed main and interaction effects. The reference group to which the other groups of students are compared is, again a girl who is a low-achiever in the low-structured condition. Regarding competence satisfaction, as shown in Table 4, no main effect and no interaction effects were found. This means that after controlling for the student characteristics the main effect of condition was faded out. Based on this full model the adjusted predicted means for the different groups of students are calculated and depicted in Figure 5 to get insight in what this means regarding the different groups of students. Pairwise comparisons between similar groups in both conditions revealed that high-achieving boys reported a significantly higher competence satisfaction in the high-structured condition compared high-achieving boys in the low-structured condition (see (b) $\chi^2 = 6.28$, $df = 1$, $p = 0.01$). No significant differences were found regarding the others groups.

Figure 5. Graphical representation of the adjusted predicted means of students' reported competence satisfaction (7-point likert scale). (a), (b), (c), and (d) indicate that the differences in competence satisfaction expressed in the post-test of these groups has been compared and resulted in following statistics: (a) $\chi^2 = 0.80$, $df = 1$, $p = 0.37$; (b): $\chi^2 = 6.28$, $df = 1$, $p = 0.01$; (c): $\chi^2 = 0.17$, $df = 1$, $p = 0.68$; (d) $\chi^2 = 0.59$, $df = 1$, $p = 0.44$. * indicates a significant difference between both groups at $p < .05$.

Regarding competence frustration, as shown in Table 5, the significant main effect of condition subsists after controlling for student characteristics ($\chi^2 = 5.09$, $df = 1$, $p < .02$) and in addition a significant main effect was found for gender ($\chi^2 = 12.15$, df = 1, $p < .001$) with boys indicating less competence frustration than girls. No main effect was found for achievement level and no interaction effects were found with condition. Figure 6 depicts the adjusted predicted means for the different groups of students in order to visually represent the results of this full model. Pairwise comparisons between similar groups in both conditions revealed that both low-achieving girls and low-achieving boys in the low-structured conditions expressed a significantly higher competence frustration in the low-structured conditions compared to similar students in the high-structured condition (see (a) $\chi^2 = 5.11$, $df = 1$, $p = 0.02$ and (c) $\chi^2 = 5.09$, $df = 1$, $p = 0.02$). No significant differences were found regarding the high-achieving boys and girls in both conditions.

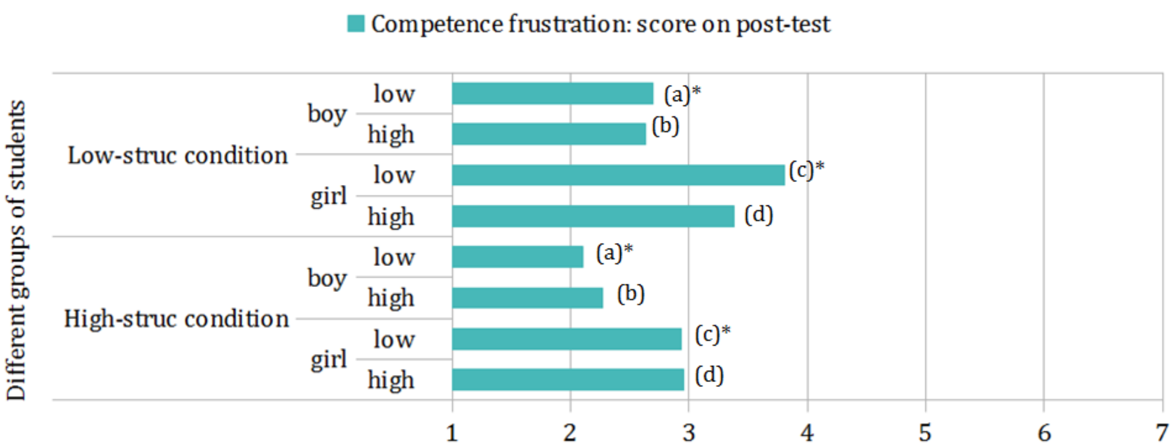

Figure 6. Graphical representation of the adjusted predicted means of students' reported competence frustration (7-point likert scale). (a), (b), (c), and (d) indicate that the differences in competence frustration expressed in the post-test of these groups has been compared and resulted in following statistics: (a) $\chi^2 = 5.11$, $df = 1$, $p = 0.02$; (b): $\chi^2 = 2.0$, $df = 1$, $p = 0.16$; (c): $\chi^2 = 5.09$, $df = 1$, $p = 0.02$; (d) $\chi^2 = 1.48$, $df = 1$, $p = 0.22$. * indicates a significant difference between both groups at $p < .05$.

Discussion and conclusion

Although there is no disagreement that teacher interaction is critical to students' inquiry learning with technology, teachers are often not used to embed complex student-oriented, open-ended inquiry processes in their curriculum and it is not clear how they should act within a technology-enhanced classroom in which students are already scaffolded through embedded technology-enhanced hints and prompts and through interacting with peers. This study implemented and investigated the effects of two differently designed classroom scripts defining the teacher-led interventions during the course of the WISE Climate Change project. First, it was questioned how the design of the teacher-led class interventions contributed to students' knowledge integration and their basis need satisfaction (RQ1). Second, an important question was if aptitude-by-treatment interactions based on the student characteristics gender and achievement level could be revealed (RQ2).

Based on previous research stressing that teacher-led discussions are an important aspect of well-designed science instruction aiming students to connect science ideas for deeper understanding (Kollar et al., 2011; Linn et al., 2004), it was hypothesized that the high-structured classroom script with higher levels of structure and feedback provided by the teacher during plenary sessions would lead to higher knowledge integration and a better need satisfaction. The results of the multilevel modeling indicated that students' group performances did not significantly differ between both conditions, yet, regarding students' individual learning outcomes it was found that students in the high-structured condition achieved higher learning gains in the high-structured condition compared to the low-structured condition. However, after controlling for the student characteristics gender and achievement level, this effect did not remain significant and no significant main and interaction effects were found after including the student characteristics in the knowledge integration model. Next to questioning the effect on group performance and knowledge integration, effects were investigated on students' need satisfaction. Regarding competence satisfaction, although it was found that, overall, students in the high-structured condition expressed a higher competence satisfaction compared to students in the low-structured condition (χ^2 = 4.20, *df* = 1, *p* = .04), this effect faded out after controlling for the student characteristics. Regarding competence frustration on the other hand the significant main effect of condition subsists after controlling for student characteristics (χ^2 = 5.09, *df* = 1, *p* < .02) and in addition a significant main effect was found for gender (χ^2 = 12.15, *df* = 1, *p* < .001) with boys indicating less competence frustration than girls. To more concretely answer the second research question, based on the results of the full models for knowledge integration, competence satisfaction and competence frustration, the adjusted predicted means were visually represented and pairwise comparisons were conducted. Is was found that high-achieving boys expressed a significantly higher competence satisfaction in the high-structured condition compared to high-achieving boys in the low-structured condition (χ^2 = 6.28, *df* = 1, *p* = 0.01). This can be connected with the finding of a marginal effect indicating that these students achieved a higher learning gain in the high-structured condition. Regarding competence frustration, pairwise comparisons between similar groups in both conditions revealed that both low-achieving girls (χ^2 = 5.11, *df* = 1, *p* = 0.02) and low-achieving boys (χ^2 = 5.09, *df* = 1, *p* = 0.02) in the low-structured conditions expressed a significantly higher competence frustration in the low-structured conditions compared to similar students in the high-structured conditions.

Based on these results, the hypothesis which was stated regarding the first research question, namely that the high-structured condition will lead to higher knowledge integration and a better need satisfaction, can only partly be confirmed. No significant effects between both conditions were found regarding students' knowledge integration, yet it was found that teacher-led class interventions significantly lowered students' competence frustration. These results support the premise of the self-determination theory that teacher's behavior and the resulting classroom interaction have an important impact on students' basic need satisfaction (Vansteenkiste et al., 2009). Within the framework of SDT, it is maintained that a learning environment that facilitates the satisfaction of students' basic needs will foster autonomous motivation and in turn will lead to higher learning gains. Although this study did not find evidence for the transfer effect on learning gain, it is a step in the good direction since the conditions for learning have been improved.

Regarding the second research question testing for aptitude treatment interactions (Cronbach & Snow, 1977), the hypothesis that the high-structured condition would particularly benefit students with low prior knowledge (Kirschner et al., 2006; Mäkital-Siegl et al., 2011) could also be partly confirmed. Students in the high-structured condition expressed lower competence frustration, and this was especially the case for both low-achieving boys and low-achieving girls. This is promising as competence frustration is likely to result in helplessness and a lack of motivation (Deci & Ryan, 2000) for which low-achieving students are more liable to (Raes & Schellens, 2015). Teacher-led class interventions seem to be crucial to counter the experiences of competence frustration and keep these students on track. Regarding high-achieving students no differences were found between both conditions which align the hypothesis Mäkital-Siegl et al (2011) put forth in their discussion, that is that students with high learning capacity are better able to tap into the potential of the more self-directed and collaborative phases. Yet, the hypothesis that these students would benefit more from the low-structured classroom script could not be confirmed. This means that providing the teacher-led class interventions in addition to the scaffolding from other sources did not lead to an "over-scripting effect" for students with higher prior knowledge scores at the start of the project (Dillenbourg, 2002). In this respect, this study supports the movement towards a blended version of student- and teacher-centered procedures that promotes the need of empowerment of teachers as drivers of classroom activities as was already mentioned by several researchers in the field (Dillenbourg & Hong, 2008; Dimitriadis et al., 2013; Greiffenhagen, 2012; Kirschner et al., 2006).

Limitations and implications for future research

This study took place in authentic classrooms which is advantageous because of the high ecological validity, however it also has some limitations. Although detailed protocols strived for controllable interventions, still the intervention as intended by the designers can vary in its enactments by different teachers in their particular contexts. This was the case in two classes which unfortunately resulted in a reduced sample size. Another limitation and suggestion for further research is that we believe that a more detailed analysis of the teacher's assistance would be an added value, for example by finer discourse analysis techniques as conducted by Greiffenhagen (2012). This methodology would provide a better understanding of when and how certain classroom interactions successfully support the groups' actions. The multilevel analyses conducted in this research revealed significant group variances regarding the variables competence satisfaction, competence frustration and the experienced provision of structure by the teacher. This indicates a significant degree of similarity between students within the same group meaning that some groups reported higher or lower feelings of competence satisfaction or frustration than other groups in the same class, and that some groups within the same class experienced a higher or lower provision of structure by the teacher. Based on the help-seeking literature (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003), this may indicate that some groups have probably asked more help from the teacher making rounds during group work than other groups, however these interactions between the teacher and the different groups were out of the scope of this study. Future research should get insight on the interplay and synergy between the scaffolding from different sources on the different social levels to further inspire discussions around designing effective CSCL environments (Onrubia & Engel, 2012; Tabak, 2004).

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Appendix A

Exemplary test item

Explanation item	Which part of Figure B is comparable to the glass on Figure A? Check the right answer and explain your answer. ☐ The sun ☐ The cosmos ☐ The atmosphere

Figure A

Figure B

Scoring Rubric

Grade / score	Response description
0	Students have no or incorrect and irrelevant ideas in the given context.
1	Correct multiple-choice answer, but without further explanation.
2	Correct multiple-choice answer with further explanation, but rather isolated and still some incorrect and irrelevant ideas are included.
3	Students have correct and relevant ideas but do not fully elaborate links between them in the given context. They still fail to connect the relevant ideas.
4	Students recognize connections between scientific concepts and understand how they interact. They have a systematic understanding and apply this in their explanation and argumentation.

Appendix B

Krippendorff's alpha reliability estimations regarding the inter-reliability of the coded variables.

Variables		Krippendorff's alpha values
Individual Pre-test		
	IPS_Pre _Question1	0,7796
	IPS_Pre _ Question2	0,9456
	IPS_Pre _ Question 3	0,7576
	IPS_Pre _ Question4	0,6270
	IPS_Pre _ Question 5	0,6885
Individual Post-test		
	IPS_Post _Question1	0,8376
	IPS_Post _ Question2	0,9039
	IPS_Post _ Question 3	0,6785
	IPS_Post_ Question4	0,7659
	IPS_Post _ Question 5	0,9291
Collaboborative knowledge construction		
	Proces_Step_1.4	0,8932
	Proces_ Step _2.2	0,7591
	Proces_ Step _2.3	0,6489
	Proces_ Step _2.6	0,6852
	Proces_ Step _2.8	0,7625
	Proces_ Step _2.10	0,9297
	Proces_ Step _2.11	0,9413
	Proces_ Step _2.12	1
	Proces_ Step _2.13	1
	Proces_ Step _2.14	0,9117
	Proces_ Step _3.2	0,9426
	Proces_ Step _3.3	0,7425
	Proces_ Step _3.4	0,6422
	Proces_ Step _3.6	1
	Proces_ Step _3.7	0,5926
	Proces_ Step _4.2	0,9528
	Proces_ Step _4.3	0,7102
	Proces_ Step _4.5	0,7772
	Proces_ Step _4.6	1
	Proces_ Step _4.9	0,8559
	Proces_ Step _5.4	0,7545
	Proces_ Step _5.5	0,9549
	Proces_ Step _5.8	1
	Proces_ Step _5.10	0,8022
	Proces_ Step _5.11	0,8148

7 General conclusion and discussion

Chapter 7
General conclusion and discussion

Abstract

This dissertation focuses on the use of computer-supported collaborative inquiry learning (CSCiL) as a promising approach for secondary science education. The series of studies are driven by three main research objectives which were discussed in detail in chapter 1 and are briefly repeated below. This final chapter provides a comprehensive discussion of the results obtained in the different empirical studies, presented in chapters 2 to 6, in answer to these research objectives. Furthermore, the strengths and limitations related to the scope of this research on the one hand and to the applied methodology on the other hand are considered. Based on the limitations and specific research findings from this dissertation, future research aspirations are proposed. This dissertation concludes with implications for educational practice.

Introduction

This dissertation deals with the question how it is possible to raise students' motivation for science learning, and at the same time, to increase achievement levels and obtain the 21st century skills that aim to prepare students for complex professional tasks in increasingly complex workplaces. This is an important question to address considering an increasing recognition of the importance and economic utility of scientific literacy in an industrialized society on the one hand, but a significant decrease in scientific literacy and motivation for science on the other hand (PISA, 2012; Woodgate, Stanton Fraser, & Crellin, 2007). Moreover, as all individuals, whether they are practicing scientists or not, need a level of science literacy that allows them to participate in public discourse and debate (Wiley et al., 2009), it is important to know how we can provide equitable learning opportunities for science learning reaching all students, regardless of gender and achievement level.

This dissertation focused more particularly on computer-supported collaborative inquiry learning (CSCiL) as a promising approach to improve science education according to the needs of the 21st century. A key aspect of science understanding is the integration of knowledge into a framework consisting of relations among concepts and principles. To obtain that, well-designed science instruction plays an important role in enabling students to connect science ideas for deeper understanding (Linn, Eylon, & Davis, 2004). Students need to make connections themselves and this process can be fostered by CSCiL (Linn & Eylon, 2011, Puntambekar, Stylianou, & Goldstein, 2007). However, what students learn in science class is often the product of scientific studies, not the process of doing science. But by presenting science as facts and not as a research process, students do not get a full appreciation that science is about doing inquiry, reasoning from evidence and constructive integration across information sources. By introducing CSCiL in science classrooms, the development of general inquiry abilities

(Bransford, Brown, & Cocking, 2000; Krajcik et al., 1998) and the acquisition of more specific information problem solving skills (Driver, Newton, & Osborne, 2000; Wiley et al., 2009) are targeted. Moreover, this learning and instruction approach gives the opportunity for collaborative learning and collaborative problem solving using appropriated information and computer technology more specifically, which is nowadays seen as a critical and necessary skill across educational settings and in the workforce (OECD, 2013). Finally, it is found that connecting science to everyday life is crucial, since such connections can trigger changes in students' motivational structure toward more intrinsic orientations (Bennett, Lubben, & Hogarth, 2007; Mistler-Jackson & Songer, 2000; Nieswandt & Shanahan, 2008). Research shows that by reflecting, applying ideas, and collaborating with peers, students develop a sense of the relevance of science (Bransford et al., 2000).

Although implementing CSCiL in educational practice is supported by national standards and educational policy (OECD, 2009; VLOR & VRWI, 2008), and despite the merits of this learning approach revealed by educational research, the implementation in science classroom settings is still limited (Pynoo, Kerkaert, Goeman, Elen, & van Braak, 2013). Also, from a theoretical point, several gaps in research could be discovered and research so far does not seem to tell the whole story about CSCiL.

First, the effect of CSCiL on disadvantaged students in science is lacking (Park, Khan, & Petrina, 2009), but is invaluable to inform policy and practice about how equitable learning opportunities in science can be provided. Second, it is known that participation in CSCiL does not automatically guarantee the educational potential of CSCiL. It is not enough for a student to be allocated to some group work, or for them to have access to some supportive technology. In this regard, a crucial question is how the learning environment and the appropriate scaffolding – as a system in which learners, tools and teachers work together – need to be designed to benefit science learning of all students (Dillenbourg, Järvelä, & Fischer, 2009; Goodyear, Jones, & Thompson, 2014).

Aiming to fill these gaps, three main research challenges for further research have become apparent and can be summarized in three broad research questions.

Research question 1 (RQ1): **What** can be achieved by means of computer-supported collaborative inquiry learning or what is the impact on students' knowledge achievement, students' inquiry skills, and students' motivation for science learning?

Research question 2 (RQ2): For **whom** is this learning approach suitable and beneficial and can we identify aptitude-by-treatment interactions based on student characteristics?

Research question 3 (RQ3): **How** should CSCiL be put into practice taking into account the everyday classroom context in which scaffolding needs to involve teacher, peers, and technology?

These research questions are considered particularly in the context of secondary science education (grades 9 and 10, i.e. 16 years old on average) and are unraveled within five consecutive studies. As stated in Chapter 1, overall, the research in this dissertation has been influenced by the design-based research (DBR) approach since the research studies were all carried out in the context of the implementation of computer-supported collaborative inquiry learning in authentic classrooms. As described in Chapter 1 and Chapter 2, it was decided to use the existing Web-based Inquiry Science Environment (WISE) and a WISE curriculum project about Global Climate Change was developed based on the instructional pattern of the Knowledge Integration approach to learn about the underlying scientific phenomena. Generally, the same project was implemented in authentic classrooms during the five iteration studies, yet, after each intervention the project design and the given support and guidance were adjusted to refine the results regarding the three research objectives. This means that all three research objectives were repeatedly discussed throughout the subsequent studies. Besides that, it needs to be noted that although the overall dissertation can be linked with the characteristics of DBR, the several studies can be regarded as stand-alone quasi-experimental research studies which investigate intervention effects in naturally constituted classes assigned to either an experimental or a control condition (Koul, 2009).

In the subsequent paragraphs the results from the empirical studies depicted in Figure 1 will be discussed regarding the three research objectives.

Overview and discussion of the main results

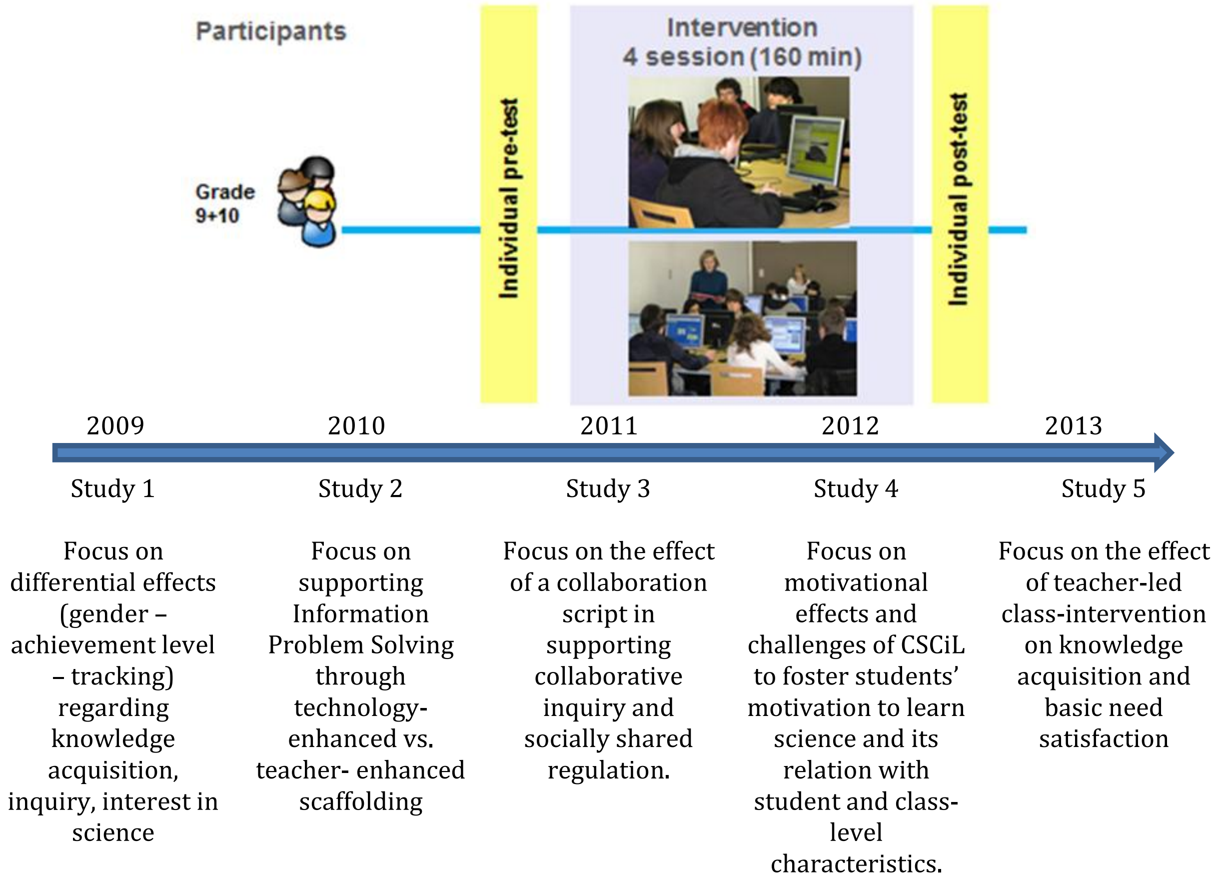

Figure 1. Overview of the five studies conducted based on the design-based research (DBR) approach

Study 1

The first study, described in Chapter 2, reports on the first implementation of the WISE project in 19 secondary classes, involving 370 students, and focuses specifically on gender, achievement level, and academic track. Multilevel analysis was applied to uncover the effects on knowledge acquisition, inquiry skills, and interest in science. Thus, this chapter generally builds on the first two research objectives, that is (1) what can be achieved and (2) for whom is it most suitable and beneficial. Based on previous research, it was hypothesized that CSCiL can benefit a diverse population of students, including disadvantaged students in science. In an attempt to close the gender gap, first it was hypothesized that CSCiL can benefit girls due to the opportunity to share and discuss ideas about science topics connected with everyday life. Second, in an attempt to provide equitable learning opportunities for high- and low-achievers in science, it was hypothesized that CSCiL can also benefit low-achieving students in science, as the knowledge integration approach considers the ideas of all learners and gives all students the chance to express their thoughts working at their own pace. And third, it was hypothesized that this learning approach is suitable and beneficial for science as well as general-track students as it can counter the prominent self-fulfilling prophecy.

Whereas most previous studies only included one factor in isolation, for instance gender, without taking into consideration the complex situation that arises when these different factors interact, this study tested the main and interaction effects of gender, achievement level, and academic track on the student, dyad and class level by means of a multilevel approach.

With regard to knowledge acquisition, results indicated that low prior knowledge students and students from a general-track, and more specifically low-achieving girls from a general-track, are likely to benefit from CSCiL as an intervention which can elicit achievement boosts (Bandura, 1986). The higher learning gains for disadvantaged students could be explained by the integrated design principles which promote knowledge integration (Bell & Linn, 2000). By applying CSCiL, students can discuss science topics in small groups, which is less threatening than in front of the whole class. Furthermore, this teaching approach is less liable to a teacher's self-fulfilling prophecy as every student gets the chance to engage in high-level inquiry learning and to show his/her capacities.

Besides knowledge acquisition, this study aimed to promote an atmosphere of inquiry and investigated whether students' inquiry skills were enhanced after the web-based inquiry science project. Inquiry skills were measured by focusing on identifying the research question, hypothesis generation, and planning of an investigation. Students' scores on the inquiry test significantly improved and different groups of students equally benefitted from the intervention.

Finally, the intervention aimed to improve students' interest in science. The results indicated that implementing CSCiL in classroom settings can trigger positive changes in some students' interest in science. Interestingly, a slight but significantly positive change in interest in science was found for female students. Although girls started the project with a significantly lower interest in science, the girls achieved the highest gain in interest in science which consequently narrowed the gap between girls and boys since after the intervention, boys and girls reported an equal interest in science.

Study 2

Chapter 3, described the study in which the WISE project was implemented for the second time. Although the first study found that students' scores on the general inquiry test significantly improved, an important finding based on students' enactments during the first intervention was also that students often struggled when searching the web during the inquiry activities. One of the problems which was previously described by Wallace, Kupperman, Krajcik, and Soloway (2000) was that students seek to find the right answer on a specific page instead of integrating information from different sources and some students even indicated that they did not find anything on the web. Based on this emerging issue, the focus on inquiry skills had been narrowed from general inquiry skills to science inquiry on the web or information problem solving (Brand-Gruwel, Wopereis, & Walraven, 2009) as a prerequisite for successful CSCiL. Moreover, next to questioning "what" can be achieved (RQ1) and "for whom" (RQ2), the second study also partly challenged the third research question about "how" to support students during science inquiry (RQ3) and investigated possible aptitude-by-treatment interactions (RQ2). A quasi-experimental study has been set up to investigate the impact of technology- and/or teacher-enhanced scaffolding on students' science learning and to explore the interaction effects with students' characteristics, which were gender and achievement level. The intervention study aimed to improve knowledge achievement and metacognitive awareness during information problem solving as part of CSCiL. In total, 347 students from 18 secondary school classes were involved and the classes were randomly distributed over the four conditions (i.e. three experimental conditions: teacher-enhanced scaffolding, technology-enhanced scaffolding, and both forms of scaffolding and a control condition).

Results of this study confirmed what was already found in the first study regarding RQ1, that is, that learning science by means of a CSCiL is effective to enhance learners' knowledge acquisition. Moreover, this study confirmed that science inquiry on the web provides the opportunity to enhance students' metacognitive awareness during information problem solving (Wiley et al., 2009). However, this study gave also insight regarding the third research question, the "how" question and regarding RQ2 since it was questioned if the way students were scaffolded interacted with students' personal characteristics. Results showed that the benefits significantly differed based on the scaffolds students were provided with.

With regard to knowledge acquisition, teacher-enhanced scaffolding was found to be a determining factor. Students provided with teacher-enhanced scaffolds facilitating the information problem solving skills and metacognitive processes, reached statistically significant higher knowledge achievement scores compared to students in classes without teacher-enhanced scaffolding. Moreover, a significant aptitude-by-treatment interaction was found regarding students' achievement level. Although high-achieving students performed equally on the knowledge post-test irrespective of the way they were scaffolded, low-achieving students performed significantly better in the condition with teacher-enhanced scaffolds or in combination with technology-enhanced scaffolds in comparison with the condition without teacher-enhanced scaffolds. This implies that human interactions with the teacher proved to be important, especially for low-achieving students, and can be explained by the fact that the teacher can dynamically monitor the information processes and help them to overcome their lack of domain knowledge. On the other hand, high-achieving students performed successfully regardless of the scaffolding condition. These findings were consistent with previous research that stressed that students with insufficient prior knowledge can suffer from minimal guidance (Kirschner, Sweller, & Clark, 2006) and with Kim and Hannafin (2011), who suggested that learners who lack adequate prior knowledge need a teacher or human tutor who can scaffold or model information problem solving. With regard to gender, only a marginally significant aptitude-by-treatment interaction was found. A remarkable finding was the fact that whereas the combined condition was the most beneficial one for girls, this was not the case for boys, for whom the teacher-scaffolded condition was the most beneficial. This finding could be explained by the fact that the combination of both modes of scaffolding may produce an "over-scripting effect" as conceptualized by Dillenbourg (2002) for boys. The technology-enhanced scaffolds guided students' IPS, but if the learner already has an internal script of how to fulfill the task, the performance of the learner might decrease (Stegmann, Mu, Gehlen-Baum, & Fischer, 2011). Moreover, the finding that the combined condition was not effective for boys could be related with the fact that in other research (e.g. Ford, Miller, & Moss, 2001; Large, Beheshti, & Rahman, 2002; Liu & Huang, 2008; Roy, Taylor, & Chi, 2003) boys were found to encounter less disorientation problems and generally feel themselves able to find their way around more effectively, and they do feel more in control compared to girls.

With regard to the improvement of metacognitive awareness during IPS, technology-enhanced scaffolding alone or in combination with teacher-enhanced scaffolding was most beneficial. Providing students with teacher-enhanced scaffolds but without incorporation of the embedded prompts, however, ended in significantly lower metacognitive improvements. No aptitude-by-treatment interactions were found regarding students' characteristics. This means that all students equally benefitted from the intervention to improve their metacognitive awareness as long as they were provided with the technology-enhanced scaffolds. The technology-enhanced scaffolds providing prompts as part of an external script supported the internalization of metacognitive skills so that learners can apply the acquired knowledge to self-prompt actions in similar situations (Wang, Kollar, Stegmann, & Fischer, 2011).

Study 3

Study 3, outlined in Chapter 4, was set up to counter a limitation of previous studies, more specifically that learning effects were measured individually whereas the collaborative work can mediate these effects. Collaboration is recommended since it has been found that student dyads are generally better in applying (information) problem solving (IPS) strategies and yield higher learning outcomes compared to students who work individually, yet, successful collaboration and shared regulation is not guaranteed and not all dyads collaborate in the same way (Rummel & Spada, 2005). Building on this issue, this study aimed to investigate the regulatory processes that come into play during collaborative IPS and to find out if these processes can be supported by providing students with a collaboration script. Thus, this study partly fits in with the first research question taking into account the collaborative problem solving skills and partly the third research question by questioning how collaboration can be supported. For this study, the WISE project was implemented for the third time, and involved 202 students working in pairs, coming from 12 secondary school classes. Six classes were provided with a collaboration script embedded in the learning environment, while the other six classes acted as the control group. In the attempt to improve shared regulation during information problem solving, a collaboration script was developed which distributed the cognitive and metacognitive responsibilities and was intended to stimulate the reciprocal process of questioning and prompting in peer interactions. It was hypothesized that students in the script condition would yield higher socially shared regulation than students in the control condition without collaboration scripts. Unfortunately, no significant improvement in socially shared regulation was found that could be attributed to the classroom script intervention. Moreover, the qualitative results derived from contrasting dyads which were selected on the basis of their group performance scores indicated no straightforward difference between the scripted and unscripted groups. Although this finding is contrary to several studies which present positive results of a collaboration script (see e.g. Kollar et al., 2007; Rummel & Spada, 2005; Schoonenboom, 2008), it is in line with Linn and Eylon (2011), who noticed that scripting may reduce the spontaneous generation of personally unique contributions which is a potential advantage of collaboration. Moreover, Chiu and Kuo (2009) pointed out that although roles are assigned, group members often mutually organize each other's roles and distribute responsibilities dynamically, depending on their needs and skills. Determining a specific role for each of the participants requires that students have the skills to perform the role, but also the belief of their peers that they can perform the role. Scripted roles can fail if students are assigned roles which they cannot perform or do not feel comfortable with. Giving students more choice in taking up a role and playing according to their strengths probably would lead to better results.

Second, in line with the strong consensus that successful learners self-regulate their learning by using a repertoire of strategies while completing tasks, it was hypothesized that better shared regulation would lead to better co-constructed knowledge. This hypothesis was partly confirmed by both quantitative and qualitative results. The quantitative results revealed that performing a task analysis significantly predicted better group performances, yet the other strategies (e.g. examining the reliability of sources) did not significantly influence the group performances. Qualitative results showed that the information processing of the successful groups was characterized by adequate task analysis and activation of prior knowledge, revision of pieces of evidence, questioning of the relevance and reliability of the sources and comparison of different sources used in the final answer. The collaborative process of the worst performing groups on the other hand was characterized by superficial information processing, students picking the first ranked source without source evaluation, and copy-pasting part of the source in the answer. These results are consistent with findings that regulative team activities can lead to better learning results (Saab, van Joolingen, & van Hout-Wolters, 2012) and with Brand-Gruwel, Wopereis, and Vermetten, (2005), who found that compared with novices, experts in IPS spend more time on the main skill (“define the problem”) and more often activate their prior knowledge, elaborate on the content, and regulate their process.

Finally, this study also questioned if the overall implementation improved students’ individual metacognitive skills and if the intervention helped the students to learn more strategies and perform better in terms of argumentative writing. It was found that CSCiL improved students’ metacognitive awareness, which is consistent with the finding from Study 2 (described in Chapter 3) and with Chiu and Kuo (2009), who stress that social metacognition supported by a technology-enhanced learning environment can facilitate learning of individual metacognition. Moreover, improvement for some students was found in students’ strategy use and students’ performance in argumentative writing; however, still 70 % of the students did not note the source of their argumentation. The construction of evidence-based arguments remains for most of the students a complex task which deserves further attention (Belland, Glazewski, & Richardson, 2008).

Study 4

The fourth study described in Chapter 5, focused more deeply on one of the objectives in science education, that is, motivation for science learning by unraveling the motivational effects and challenges of CSCiL to foster students’ motivation to learn science and its relation with student and class-level characteristics. Thus, again this study partly fits within the three overall research questions of this dissertation. An empirical mixed methods study in 13 secondary science classes was conducted, involving 220 students. The Self-Determination Theory (Deci & Ryan, 2000) was used as a theoretical lens through which students’ motivation in CSCiL was analyzed. It was hypothesized that CSCiL on the web can be considered as a need-supportive environment which in turn can foster autonomous motivation, which was measured quantitatively. In addition, qualitative analyses were conducted on students’ experiences and future preferences regarding the WISE project to inform further refinement of the design of the implementation.

Regarding the effects on autonomous motivation, multilevel analyses revealed that although general track students had a significantly lower motivation for science prior to the intervention, these students realized a significant improvement in motivation, whereas science track students’ motivation, which was already high, did not significantly changed. Based on these results, we can state that the hypothesis of an increased autonomous motivation for science learning is not entirely confirmed, but only holds for general track students. This result is however promising and in line with the findings of the first study given the fact that general track students are often disadvantaged in science in the way that they often receive less challenging instruction consisting of teacher-centered knowledge transmission (Oakes, 2005). Results moreover revealed that students from a general track are more positive about using WISE in future science education. It seems that these students more appreciated the social, active, and constructive learning process, which is confirmed by the qualitative results: e.g., *“It was fun working together,”* and *“You’re really working on the content, you’re going to remember it more easily if you* *need to explore it by yourself and formulate the answers, much better than 'cramming' things you actually do not understand and you will forget almost immediately.*" Students from a science track, on the other hand, are more likely to indicate that they no longer want to be taught in this way. One of the reasons was that they experienced a lower learning gain and that they understand it much better if the teacher explains the content and they do not have to investigate everything by themselves. With regard to gender, boys were more likely to indicate that they would like to be taught by means of WISE and girls were more likely to express the conditions under which they would like WISE to be used in the future. Students' critical feedback was of great value to reveal design guidelines to optimize the implementation of CSCiL in future science education in light of the satisfaction of the basic needs according to the Self-Determination Theory, that is autonomy, competence and relatedness (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). The main finding was that a lot of students stressed that they would only like to be taught with WISE in combination with traditional teacher-centered education. This finding could be related with the fact that students need to adjust to new relationships in CSCiL with the teacher who becomes a facilitator rather than the primary source of information.

Study 5

The fifth and final study of this dissertation (Chapter 6) built on the results of previous studies and more specifically on the results from study 4 which raised the need to get better insight into this specific role of the teacher during CSCiL. Study 4 revealed that the WISE intervention lacking teacher-led class interventions was one of the drawbacks mentioned by some students who had experienced CSCiL in authentic science education. Next to this, in study 2 we found that when a teacher is actively involved in the learning process and interacts with groups of students to monitor their (information) problem solving, this particularly benefits girls and low-achieving students. In this regard, this final study mainly focuses on the third research question about how CSCiL should be put into practice taking into account the everyday classroom context. Effects were investigated on students' knowledge achievement and students' basic need satisfaction and aptitude-by-treatment interactions with students' characteristics were examined, which fits with RQ1 and RQ2 of this dissertation. A quasi-experimental study was set up to investigate the effects of two differently designed classroom scripts that guided the teacher-led interventions during the courses of the WISE Climate Change project. 168 students from 10 classes were randomly assigned to either the high-structured condition (teacher interventions during group work and on class level) or the low-structured condition (only teacher interventions during group work). Effects were measured on students' knowledge integration and students' need satisfaction. The results did not provide evidence that the high-structured condition led to higher learning gains, yet it was found that pausing the group work during CSCiL to provide structure and feedback by the teacher at a whole-classroom plenary level significantly lowered the feelings of competence frustration. Moreover, a significant aptitude-by-treatment interaction was found regarding low-achieving students who expressed higher competence frustration in the low-structured condition. These findings suggest to blend computer-supported collaborative learning with teacher-led class interventions to optimize the learning environment.

To conclude, the main results of the studies regarding the three main research questions of this dissertation can be summarized as follows.

Research question 1 (RQ1): **What** can be achieved by means of computer-supported collaborative inquiry learning?

- Implementing CSCiL resulted in significant improvements of students' knowledge integration, meaning that students made significant progress in connecting ideas in their explanations regarding climate change.
- Implementing CSCiL improved students' general inquiry skills including identifying the research question, hypothesis generation, and planning of an investigation. Moreover, CSCiL on the web provided the opportunity to enhance students' metacognitive awareness and strategy use during information problem solving which in turn resulted in better argumentative writing products.
- Implementing CSCiL supported basic-need-supportive teaching which in turn fostered students' autonomous motivation and interest towards science learning.

Research question 2 (RQ2): For **whom** is this learning approach suitable and beneficial and can we identify aptitude-by-treatment interactions based on student characteristics?

With regard to gender:

- Male and female students equally benefited from CSCiL with regard to knowledge achievement and inquiry skills. Regarding interest in science girls were found to achieve the highest gain in interest, which narrowed the gap between girls and boys as they reported an equal interest in science after the intervention.
- A marginal significant aptitude-by-treatment interaction was found regarding gender in the second study. Whereas female students benefited most when both teacher- and technology-enhanced scaffolding were provided in combination, male students benefited most when only teacher-enhanced scaffolding were provided. In that sense, male students were found to be more sensitive to an "over-scripting effect" as teacher-enhanced scaffolding in combination with technology-enhanced scaffolding was not effective for male students. Yet, this "over-scripting" effect regarding gender was not confirmed by the final study in which teacher-led class interventions were added to support students during science inquiry.
- Male students experienced significantly lower levels of competence frustration during CSCiL compared to female students.
- Male students were more likely to indicate that they would like to be taught by means of CSCiL in future science education. Female students did not express more reluctance, but

they were more likely than male students to express the conditions under which they would like to be taught by means of CSCiL.

With regard to achievement level:

- Low-achieving students realized significantly higher learning gains compared to high-achieving students.
- Aptitude-by-treatment interactions were found which revealed that low-achievers realized higher gains in knowledge achievement when supported by teacher-enhanced scaffolding during group work in addition with technology-enhanced scaffolding. Moreover, low-achieving students experienced lower competence frustration feelings when teacher-led class intervention was provided during CSCiL.

With regard to academic track:

- General track students achieved significantly higher knowledge integration learning gains compared to science-track students.
- General track students realized a significant improvement in autonomous motivation, whereas science track students' motivation did not significantly change.
- General track students were more positive compared to science track students regarding using CSCiL in future science education.

Research question 3 (RQ3): **How** should CSCiL be put into practice taking into account the everyday classroom context in which scaffolding needs to involve the teacher, peers, and technology?

With regard to the teacher as a source for scaffolding:

- To adequately support a diversity of students during CSCiL which aims at knowledge acquisition as well as at improving (information) problem skills and motivation for science, the teacher has an invaluable role to meet students' basic needs of autonomy, relatedness and competence. Both teacher-enhanced scaffolding during students' group work and teacher-led class intervention are found to improve the benefits of CSCiL. Teacher-enhanced scaffolding is especially important for low-achieving students and girls and teacher-led class intervention are found to lower the competence frustration of low-achieving students and do not hamper the high-achieving students.

With regard to the peers as a source for scaffolding:

- Collaboration and interaction are highly valued in CSCiL since students are encouraged to learn from each other in collaborative activities, including debate, creating a group artifact, and constructing an argument. This feature moreover fosters the need for relatedness which is important to improve motivation for science. Next, it was found that better shared regulation leads to better co-constructed knowledge, however no significant improvement in socially shared regulation was found that could be attributed to the collaboration script intervention.

With regard to technology as a source for scaffolding:

- Embedding technology-enhanced scaffolding (i.e. prompts and hints as part of an external script) is found to positively influence the metacognitive awareness and strategy use during information problem solving. These findings support the possible internalization of strategic knowledge so that learners can apply the acquired knowledge to self-prompt actions in similar situations.

The studies included in this dissertation are enriched by diverse theoretical insights from different, but related, research areas, such as knowledge integration (e.g., Slotta & Linn, 2009; Linn & Eylon, 2012), information problem solving (e.g., Brand-Gruwel et al., 2009; Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012), (socially shared) metacognition and regulation (e.g., Chiu & Kuo, 2009; Greene & Azevedo, 2010; Järvelä et al., 2014), motivation from a self-determination perspective (Deci & Ryan, 2000; Vansteenkiste et al., 2009), scaffolding (Graesser et al., 2007; McNeill & Krajcik, 2009; Puntambekar & Kolodner, 2005), and scripting (Dillenbourg & Hong, 2008; Fischer, Kollar, Mandl, & Haake, 2007); in turn, this dissertation also contributes to these theories and their related empirical base in some important ways. Researchers from different theoretical orientations or rooted in different educational research fields can therefore take advantage of the proposed studies and results.

Strengths, limitations, and suggestions for future research

The research described in the current dissertation has, as with all research, both strengths and limitations. The contributions and limitations related to the individual studies are described in the previous chapters. In this chapter, the general strengths and weaknesses of the research are discussed and linked to corresponding suggestions for future research.

Issues regarding the scope of this research

Doing research includes indisputably a sequence of decisions and choices, made to balance the proposed goals with given constraints. This dissertation focused on the use of Computer-Supported Collaborative inquiry Learning (CSCiL) as a promising approach for secondary science education. Yet, it needs to be noted that CSCL refers to more learning contexts than the one described in this dissertation. CSCL refers to any situation in which computer technology plays a significant role in shaping the collaboration (Goodyear et al., 2014), including learning that takes place face to face (F2F), at a distance, and in blends of F2F and distance learning. This dissertation however only included the F2F CSCL variant in which learners are learning collaboratively, and in which technology plays a significant role in shaping the nature of their interactions with each other and supporting their collaborative activities.

Next to this, it was decided to use the existing Web-based Inquiry Science Environment (WISE) and a WISE curriculum project about Global Climate Change has been developed in co-design with Flemish science teachers based on the instructional pattern of the Knowledge

Integration approach. However, many more inquiry learning environments have been developed world-widely in the context of Computer-Supported Collaborative Learning (CSCL), for example BGuILE (Reiser et al., 2001), Co-LAB (van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005), and nQuire (Anastopoulou, Sharples, & Ainsworth, 2012). Although the main purpose in this dissertation was to study the learning processes involved in CSCL to be able to relate these to learning outcomes and in order to expand our knowledge about how CSCiL should be supported regardless of the specific learning platform, we need to be careful in making generalizations regarding the effects of learning with other learning platforms. Besides, a curriculum project about Global Climate Change was developed with great effort as this project theme could integrate the sciences of physics, chemistry, biology, and geography. In this regard, a good practice was provided to the educational practice of how to apply an integrated science teaching approach that is increasingly stressed by educational policy and national standards. Yet, other project topics would have been possible and might have resulted in different results.

In addition, besides the choice for a particular inquiry learning platform, in the context of this dissertation students worked collaboratively around a shared laptop or desktop. However, technological innovations go fast and more and more CSCL research started to investigate collaboration as it occurs around mobile devices (Zurita & Nussbaum, 2007), virtual worlds (Girvan & Savage, 2010), interactive whiteboards (Kershner, Mercer, Warwick, & Kleine Staarman, 2010), or interactive tabletop devices (Courtois et al., 2014). Future research should investigate the added value of mobile technology with respect to the effects for science learning.

With respect to the problem statement outlined in Chapter 1, we have to acknowledge that the development of positive attitudes toward science is an ongoing process (Machina & Gokhale, 2010). Although the present study provides positive and promising results to provide equitable learning opportunities and attracts a more diverse public for science, it should be recognized that in order to maintain positive attitudes toward science and to ensure that young people are open to participating in science in higher education, an isolated inquiry project addressing a single science topic may not be sufficient. We need to investigate the implementation of CSCiL for more extended periods of time and across different science topics.

Finally, as indicated in the introduction chapter, this dissertation built upon the premise that in everyday classroom teaching, scaffolding needs to involve teacher, peers, and technology (Kim & Hannafin, 2011). Overall, this dissertation took into account the different sources of scaffolding; however, each study separately zoomed in on one or two of the sources which were studied in a quasi-experimental design. An important next step in research and development is to understand the interplay and synergy between students, peers, technology, and the teacher. Yet, one of the most fundamental problems which should be taken into account is "context". The highest challenge of design-based research is that research is conducted in the "blooming, buzzing confusion" of classroom learning environments (Brown, 1992). Many variables can influence the success of a design, and many of those which cannot be controlled which makes it difficult to assume universality (Hoadley, 2004). This brings us to the methodological challenges of this dissertations discussed below.

Methodological issues

One of the methodological strengths of this dissertation is that all studies were conducted in real-life classroom contexts. In this regard, high ecological validity was guaranteed compared to studies in lab settings. Moreover, the studies were conducted on a relatively large scale, given the design and scope of this research. To make large scale implementation of the CSCiL project possible, Master's students in the Educational Studies program were closely involved in the implementation and data-analysis for the different studies. At least two Master's students were present in each participating class during the whole intervention. This collaboration between Master's students and teachers in secondary education had several advantages. First, Master's students could be thoroughly trained beforehand to use the learning platform and to implement the WISE project according to the specific protocol and instructional principles in each specific study and condition. In study one to study four, the Master's students served as the actual teachers during the project, while the regular classroom teachers predominantly observed the learning processes. In the final study, we decided to include the real science teachers as the actual teachers, but the Master's students were still available to support them. This design setting made it possible to include quality control regarding treatment validity. Although it was hard to keep the intervention parameters completely under control, a number of actions were undertaken to ensure that the intervention took place as intended. The real classroom teachers – without knowing to which condition they belonged – were asked to observe the Master's students and fill out an evaluation form evaluating the overall CSCiL project, as well as the quality of the intervention of the Master's students. This form of manipulation check informed us about how the Master's students interacted in the classroom. In the final study, the Master's students evaluated the classroom teachers to inform treatment validity.

However, besides the advantages of research in authentic settings, there are also some inherent drawbacks. As the intervention was conducted on a large scale and in a real-life context, the available time and facility to measure learning processes was limited and we were often restricted to self-report measures. It is acknowledged that the collection and processing of data associated with F2F CSCL is more time-consuming compared to that associated with synchronous or asynchronous, online CSCL (Goodyear et al., 2014). It was already hard to get arranged four hours to implement the project as teachers in secondary schools have less freedom because of the inflexible structure compared to a primary school or university setting (Dillenbourg & Jermann, 2006). The time constraints moreover had the negative consequence that only short-term impact of the intervention could be measured. Additional research using a longitudinal approach might be interesting to find out whether the impact of such intervention in science education is persistent over time.

Moreover, future research, on a smaller scale, taking a more zoomed-in perspective capturing the interaction processes between the several actors (students, groups and the teacher) and sources (technology, peers, and the teachers) at the different social levels would be valuable. Regarding the group work level, this research should use video to capture the computer screen, computer usage, gestures between students, and the direction that the students face, in addition to high-quality audio, and logfiles of sequences of actions on the computers (Perry & Winne, 2006). In addition, a second camera should be used to follow the teacher to capture the way in which the teacher organizes the whole-class intervention and to capture the work of the teacher during the periods in which students are doing group work (Greiffenhagen, 2012; Alonzo, Kobarg, & Seidel, 2012). These additional streams of data would add to the understanding of CSCL environments. From the learner's perspective, this research would give insight into what really happens in the context of the classroom during the scaffolding process to deepen the questions: Who searches for help? Who needs help? Who used the support that is offered? From the teacher's perspective, on the other hand, such research would give insight into what Macbeth (2003) has termed "naturally occurring discourse" and would for example help to investigate if female students interact more with the teacher in a computer-supported collaborative learning setting compared to a traditional classroom setting. The question is, however, if introducing these cameras into the classroom will not obstruct the natural context of learning and instruction.

Another methodological strength of this dissertation is that multilevel modeling has been used as a statistical approach which is suitable to the complexity of data obtained through a CSCL project implemented in authentic classrooms (Cress, 2008; De Wever, Van Keer, Schellens, & Valcke, 2007). Next to quantitative analyses, also qualitative approaches have been used within this dissertation from a mixed methods perspective to strengthen the inferences both in terms of processes of analysis and outcomes of analysis (Creswell, 2008; Greene, 2008). However, as already mentioned above, partly due to time and practical constraints, the measurement of the learning processes could be improved. Regarding the assessment of learning processes, thus far processes in CSCL have to be manually coded and analyzed, which is time-consuming (Reimann, 2009), however the future research should aim to further explore the automation of scoring complex data using learning analytics as the key to realize real-time assessment for learning (Griffin, Care, Bui, & Zoanetti, 2013). Moreover, automatic assessments have the potential to inform the teacher about the subsequent teaching and learning activities (Matuk, Linn, & Eylon, 2015). Future research can build on exciting breakthroughs which are being made, such as the automatic identification of reasoning displays and idea construction contributions in speech data (Gweon, Agrawal,Udani, Raj, & Rose , 2011) and by the Continuous Learning and Automated Scoring in Science (CLASS) project (TELS, 2014).

Practical implications

Obtaining 21st century skills

To prepare students for complex professional tasks in increasingly complex workplaces, schools and teachers are required by national standards and policy advisors to foster 21st century skills, including inquiry, collaboration, and critical thinking, as well as a wide spectrum of digital literacies. However, next to these cross-curricular standards, teachers are under pressure to cover the domain-specific curricular standards. This means a serious challenge for science teachers who are asked to cover the breadth of the curricular standards on the one hand and on the other hand to focus on the obtainment of 21s century skills. Moreover, teachers and schools often lack the experience and knowledge on how to meet the 21st century challenges during their educational practice and how to integrate these skills into their curriculum. This dissertation has made an important contribution to support teachers to bring inquiry and technology into their classrooms. An inquiry learning environment like WISE not only scaffolds students' activities and improves student learning, but also helps teachers in their teaching processes. The developed CSCiL project about "Global warming and Climate change" moreover provided a means for teachers to incorporate the cross-curricular attainment targets regarding digital competences into their content courses. Next to this, the WISE project served as a good practice of an integrated (versus separate-subject) teaching approach in science.

Providing equitable learning opportunities

Based on the results of this dissertation, teachers are encouraged to implement computer-supported collaborative inquiry in order to provide more equitable learning opportunities in science education. Technology-enhanced inquiry from a knowledge integration approach was found to be effective to narrowing the gap between boys and girls in science and can give low-achieving students and general-track students an opportunity to develop confidence and skills for learning science, bringing them to performance and motivation levels which are closer to that of high-achieving students in science. These results should be further disseminated towards the education practice to counter the prevalent conception that higher-order learning goals and activities in which knowledge needs to be constructed by the learners are only suitable for students with higher cognitive abilities. During the recruitment of the participating schools and classes for the different studies, it was remarkable that teachers were particularly willing to participate in the CSCiL project with students from their science-track class, as this track provides more time for such activities. This is contradictory in view of the fact that this learning approach particularly benefits students from a general track.

Empowering teachers for synergistic scaffolding

To improve the benefits of this learning approach, this dissertation has stressed that appropriate scaffolding is needed and that a traditional one-size-fits-all instructional approach will not meet the learning needs of all the students in the classroom. Based on the found aptitude-treatment interactions, we know for example that low-achievers have a higher need for teacher-enhanced scaffolding during group work and that teacher-led class intervention is important to lower competence frustration during CSCiL. In this respect, it has been claimed that during everyday classroom teaching, scaffolding needs to be distributed and involve teacher, peers, and technology. Bringing these scaffolding sources together increases the time available for the teacher to interact with students and gives the teacher the opportunity for in-class differentiation. Technological tools moreover make visualization of student learning possible which is important for teachers to do real-time assessment and monitoring (Matuk, Linn & Eylon, 2015). Teacher management tools aim to increase efficiency of teaching and individually tailored learning experiences for students which in turn can improve science and inquiry skills of students. This means that also in technology-enhanced learning, teachers are still the main drivers of classroom activities (Dimitriadis, Prieto, & Asensio-Perez, 2013). However, to make sure that teachers use the teacher management tools for what they were developed for, sustainable professional development will be an important precondition to realize an effective implementation of CSCiL. Moreover, teachers must further be supported in their efforts to design and enact curricula that will engage students in authentic forms of 21st century science practices (Madeira & Slotta, 2012).

Final conclusion

Kirschner (2015) recently stated that “education is a complex ecology of learners, educators, and technologies/media in a dynamic environment” and that “the goals of research in this ecology are the improvement of the quality of education, making contributions to the design and development of tools for education, and expansion of our knowledge and expertise in the field”. This dissertation strengthened the field by exploring this complex ecology and providing evidence about the learning effects of Computer-Supported Collaborative inquiry in science education for different groups of students and more particularly the more disadvantaged students in science. Moreover, this dissertation questioned how this learning approach should be brought into educational practice and how support should be designed to serve a diversity of students regarding the obtainment of knowledge integration, problem solving skills, and motivation in science. This chapter presented the context, overview, and discussion of the main results, the strengths, limitations, and implications for future research, and the practical implications of the dissertation. The main conclusion, however, is that supporting multiple students in a technology-enhanced classroom aiming to support scientific understanding and 21st century skills requires distributed scaffolding with multiple modes of support with each its own unique affordances. Future research is desirable to further investigate this synergetic scaffolding in complex classrooms.

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Nederlandstalige samenvatting
Summary in Dutch

Nederlandstalige samenvatting

De impact van "computerondersteund samenwerkend onderzoeken" op het leren van wetenschappen in het secundair onderwijs

Inleiding

Wetenschappelijke geletterdheid wordt door de Europese Unie gezien als een sleutelcompetentie voor levenslang leren en moet dus gestimuleerd worden bij alle leerlingen (Europese Unie, 2006). Volgens onderzoek van de Eurobarometer (Europese Commissie, 2008), het EU-instrument om de publieke opinie te analyseren, hebben jonge Europeanen, net als de oudere generaties, een algemeen positief beeld van wetenschap en technologie. Toch geeft meer dan de helft van de geïnterviewde jongeren te kennen niet geïnteresseerd te zijn om zelf wetenschappelijke of ingenieursstudies aan te vatten. Deze vaststelling wordt ook bevestigd door de resultaten van het internationaal PISA-onderzoek naar wetenschappelijke vaardigheden (De Meyer, 2008). Daaruit blijkt dat Vlaamse 15-jarigen hoge resultaten behalen voor wetenschappelijke geletterdheid, maar dat zij in vergelijking met de leerlingen in een gemiddeld OESO-land minder gemotiveerd zijn om wetenschappen te leren. Het aantal studenten dat kiest voor een wetenschappelijke en/of technische opleiding is bijgevolg laag en dit geldt voornamelijk voor vrouwelijke leerlingen (VLOR & VRWI, 2008). Enige verontrusting over deze negatieve trend in het studiegebied wetenschappen is op haar plaats, want wetenschap en technologie spelen een cruciale rol in de hedendaagse wereldeconomie. Om competitief en vernieuwend te blijven in deze disciplines, hebben we opeenvolgende generaties wetenschappers en onderzoekers nodig. We stellen nochtans vast dat jonge kinderen door hun natuurlijke leergierigheid wetenschap leuk vinden, maar hun belangstelling en plezier blijken gaandeweg af te nemen. Een van de redenen daarvoor blijkt de manier waarop wetenschap wordt onderwezen (Osborne, Simon, & Collins, 2003; Sjøberg & Schreiner, 2010).

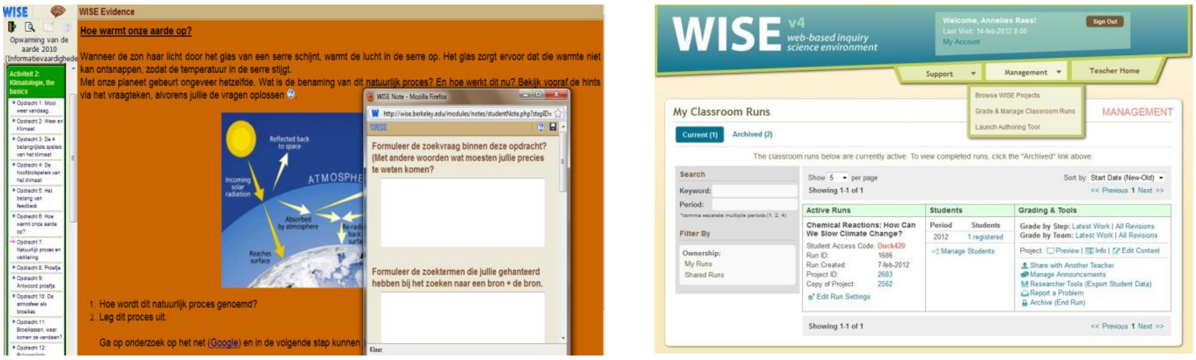
Deze bevindingen benadrukken de nood om het wetenschapsonderwijs op een alternatieve wijze vorm te geven en zo beter tegemoet te komen aan de verwachtingen en noden van onze jongeren. Daarnaast is het een uitdaging voor het onderwijs om het onevenwicht in de genderbalans aan te pakken door de uiteenlopende noden en interesses van jongens en meisjes te verzoenen. Wanneer we de vakgebonden eindtermen en leerplannen van de verschillende netten voor natuurwetenschappen (of fysica en/of chemie en/of biologie) onder de loep nemen, stellen we reeds enkele accentverschuivingen vast. Er wordt voor gepleit voor het vrijmaken van ruimte voor een creatieve verwerking van leerinhouden, ook buiten een eng gedefinieerde vakcontext. Ten aanzien van de onderwijspraktijk vragen de eindtermen dan ook meer aandacht voor innovatie en een didactische vormgeving die niet de kennisreproductie, maar het individuele en collectieve proces van kennisverwerving centraal plaatst. Er wordt meer nadruk gelegd op context en praktische toepassingen, zodat het leren van wetenschappen beter beantwoordt aan de noden en de ambities van zowel jongens als meisjes. Daarnaast wordt ook de nadruk op onderzoeksvaardigheden en het kritisch verwerken van de informatiestroom sterk aangemoedigd onder de vorm van het onderdeel "onderzoekscompetentie" dat werd toegevoegd aan de specifieke eindtermen voor het secundair onderwijs, en de vakgebiedoverschrijdende ICT-eindtermen die sinds 2007 in voege zijn.

Vandaag, een aantal jaren later, hebben de scholen al een hele weg afgelegd. Toch wordt vastgesteld dat het werken aan de onderzoekscompetentie nog te vaak los staat van de andere leerplandoelstellingen en beperkt blijft tot een vakgebied zonder horizontaal overleg met andere vakken (GO, 2013). Werken aan onderzoekscompetenties biedt nochtans de mogelijkheid om de verschillende wetenschappelijke disciplines meer samenhang te geven en concepten met elkaar te integreren (Czerniak, 2007). Ook wat betreft de ICT-competenties komen dezelfde bevinden naar voren (Pynoo, Kerkaert, Goeman, Elen, & van Braak, 2013). Het ICT-gebruik in scholen blijft vaak beperkt tot het plaatsten van documenten op de elektronische leeromgeving of om lessen voor te bereiden in plaats van tijdens de lessen. Geïntegreerd gebruik van ICT, als middel om het leren van leerlingen zowel aantrekkelijker, efficiënter, als effectiever te maken, verdient dus meer aandacht.

Computerondersteund samenwerkend onderzoeken

Computerondersteund samenwerkend onderzoeken wordt in de literatuur beschreven als een innovatieve en veelbelovende werkvorm die tegemoet kan komen aan de noden van de 21ste eeuw (Lee, Linn, Varma, & Liu, 2010; Slotta & Linn, 2009; Krajcik et al., 1998). Zoals eerder vermeld heeft onze maatschappij nood aan burgers die onderzoeksvaardig zijn, vragen durven stellen, en de gevonden antwoorden kritisch benaderen. Nieuwe media zoals het internet spelen tegenwoordig een dominante rol en doordringen zowel ons maatschappelijk leven alsook het onderwijs (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Critici beweren dat door de opkomst van internet onze kinderen en jongeren niets meer leren, dat ze geen kennis meer opdoen, dat ze alleen nog maar zoeken met Google en de gevonden informatie knippen en plakken zonder moeite te doen om die te begrijpen en te interpreteren. We kunnen het internet echter ook omarmen en het als een taak van het onderwijs zien om leerlingen kritisch te leren omgaan met het internet en de onderzoeks- en informatievaardigheden die daarbij verwacht worden aan te leren (Brand-Gruwel, Wopereis, & Walraven, 2009; Kuiper, Volman, & Terwel, 2009). Internetgebruik in de klas biedt in dit opzicht heel wat mogelijkheden om aan te sluiten bij de hedendaagse aandachtspunten en vernieuwingen in het onderwijs. Onderzoekers van de universiteit van California bundelden de didactische mogelijkheden van het computerondersteund leren en startten in 1998 met de ontwikkeling van de online leeromgeving WISE, de Web-based Inquiry Science Environment (Slotta & Linn, 2009). WISE biedt leerlingen en leerkrachten een gratis, online leerplatform voor wetenschappelijke activiteiten waarop leerlingen kunnen samenwerken bij het oplossen van verschillende taken door onder andere gebruik te maken van informatie die ze op het internet vinden (Linn, Clark, &

Slotta, 2003). Alle activiteiten worden gebundeld tot een project dat leerlingen stapsgewijs doorlopen zoals afgebeeld in Figuur 1.



Figuur 1. Screenshots van de WISE leeromgeving vanuit het perspectief van de leerlingen (links) en het perspectief van de leerkracht (rechts)

Ieder WISE-project vertrekt vanuit een wetenschappelijk probleem (bijvoorbeeld “De opwarming van de aarde”) waarover leerlingen per twee, stap voor stap meer te weten komen zodat ze op het einde oplossingen kunnen formuleren. De leerinhouden worden voorgestructureerd in enkele hoofdactiviteiten en iedere activiteit is verder opgedeeld in verschillende stappen die door de leerlingen doorlopen moeten worden. Ze krijgen hierbij de mogelijkheid hypothesen te testen door middel van computersimulaties en door informatie op te zoeken op het internet. Hun denkproces (van eigen opvattingen naar de aanvulling en correctie van die opvattingen) wordt zichtbaar gemaakt in “reflectienotities” die de leerkracht kan opvolgen of evalueren vanuit het leerkrachtenportaal. Daarnaast biedt WISE de mogelijkheid om leerlingen via een forum op het leerplatform te laten overleggen en discussiëren met de andere klasgenoten. Door het denkproces aan de hand van opgeslagen reflectienotities zichtbaar te maken, biedt WISE een ideale kans om formatief te evalueren en de leerlingen tijdig van feedback te voorzien (online of face-to-face). Als leerkracht krijg je niet alleen informatie over de wetenschappelijke kennis, maar ook over de vaardigheden en attitudes van de leerlingen.

In het kader van dit proefschrift werd het Vlaams WISE project “Klimaat onder vuur” ontwikkeld. Zoals afgebeeld in Tabel 1 fundeerden acht theoretisch onderbouwde ontwerpprincipes de ontwikkeling en de opbouw van het project binnen deze online leeromgeving voor wetenschappen. Deze principes zijn gebaseerd op een “kennisintegratie”-benadering (Linn & Eylon, 2011) die ervan uit gaat dat iedereen een bepaalde voorkennis en bepaalde ideeën heeft over wetenschap en (vaak onbewust) dagdagelijks geconfronteerd wordt met wetenschap. Onderzoek heeft de effectiviteit aangetoond van het waarderen van de ideeën die leerlingen reeds hebben over wetenschap en het gebruiken van deze ideeën als aanknopingspunt om vaak abstracte begrippen binnen de wetenschap aan te leren. Op die manier wordt kennis niet zomaar overgedragen, maar wordt kennis geïntegreerd binnen een reeds bestaand denkkader. De ontwikkelaars van WISE schuiven dan ook volgend stramien naar voren: (1) eigen repertoire van ideeën erkennen, (2) toevoegen van nieuwe ideeën/nieuwe informatie, (3) vergelijken van ideeën en (4) reflectie en integratie van ideeën/informatie.

Kennis wordt met andere woorden verworven en "geïntegreerd" door middel van onderzoek, reflectie en discussie.

Tabel 1

Deze tabel bevat voorbeeldactiviteiten uit het WISE project "Klimaat onder vuur" gebaseerd op de ontwerpprincipes voor kennisintegratie (Linn & Eylon, 2011)

Ontwerpprincipes voor kennisintegratie	Eigen repertoire van ideeën erkennen	Toevoegen van nieuwe ideeën/ informatie	Vergelijken van ideeën	Reflectie en integratie van ideeën
Wetenschappen toegankelijk maken voor iedereen	Genereren van hypothesen m.b.t de natuurlijke versus menselijke invloed op het klimaat	Het berekenen van de eigen ecologische voetafdruk (WWF website)	Het vergelijken van elkaars ecologische voetafdruk	Reflectie over de natuurlijke versus menselijke invloed op het klimaat
Aanschouwelijk maken van leerprocessen	Genereren van hypothesen m.b.t. de verschillende impact van rijke versus arme landen	Analyseren van de CO2-emissie trends over verschillende landen heen (Gapminder World)	Rapporteren van de resultaten	Connecteren van de resultaten van de simulatie met de persoonlijke hypothesen
Samenwerkend leren	Brainstorm over mogelijke argumenten van de "believers" vs. "non-believers"	Zoek evidentie voor het argument dat de natuurlijke vs. menselijke oorzaak	Standpunten vergelijken in debat	Consensus vinden omtrent de hoofdoorzaak voor klimaatverandering
Zelfwerkzaamheid en onderzoekend leren stimuleren	Onderzoeksvragen formuleren om leemtes in eigen kennis op te vullen	Zoeken naar antwoorden op de onderzoeksvraag	Kritisch evalueren van verschillende antwoorden	Connecteren van gevonden antwoorden met de eigen ideeën/antwoorden

Implementeren en ondersteunen van computerondersteund samenwerkend onderzoeken

Hoewel zowel beleidsmakers als onderzoekers de mogelijke positieve invloed van computerondersteund samenwerkend onderzoeken benadrukken, is het geïntegreerd gebruik van ICT en onderzoekend leren nog steeds gering. Een van de redenen waarom leerkrachten zich geremd voelen, is dat er te weinig kennis is over hoe een werkvorm als computerondersteund samenwerkend onderzoeken ondersteund kan worden en welke rol de leerkracht hierbinnen kan vervullen. Leren en instructie binnen een traditionele klascontext verschilt namelijk sterk van leren en instructie binnen een technologie-ondersteunde klascontext waar leerlingen samen onderzoekend leren. Leerlingen worden verwacht dat ze zelfstandig en actief (informatie)problemen oplossen, maar onderzoek toonde aan dat het op zoek gaan naar en gebruiken van betrouwbare informatie op het internet een kritische ingesteldheid en een strategische manier van werken verondersteld die de meeste jongeren niet bezitten (Brand-Gruwel et al., 2009; Eisenberg & Berkowitz, 1990). Veel jongeren missen de regulatievaardigheden zijnde oriënteren, plannen, monitoren, en evalueren. Leerkrachten van hun kant zijn vaak niet opgeleid om dergelijke werkvormen in de praktijk te brengen en gaan er al te vaak van uit dat het binnenbrengen van een leeromgeving hun rol kan/zal vervangen (Makitalo-Siegl, Kohnle, & Fischer, 2011).

Onderzoek toont aan dat ondersteuning binnen onderzoeksgerichte omgevingen cruciaal is om het leerrendement te garanderen. In de onderwijsliteratuur spreekt men in deze context van “scaffolding” of het aanbieden van “scaffolds” (Wood, Bruner, and Ross, 1976). Het begrip kent zijn oorsprong binnen de sociaal constructivistische leertheorie en is gebaseerd op de “zone van naaste ontwikkeling” (Vygotsky, 1978). Scaffolds betekenen letterlijk vertaald steigers en vormen een goede metafoor voor deze term. Steigers worden namelijk opgezet als ondersteuning van een gebouw tijdens de opbouw ervan. Wanneer het bouwproces beëindigd is, wordt de steun verwijderd en staat het gebouw bijgevolg op zichzelf. Bij instructie vervult scaffolding eenzelfde rol aangezien het de lerende helpt zijn succes te verzekeren, het breidt de lerende zijn competenties in een nieuw leergebied uit en neemt af naarmate de lerende vaardiger wordt (Hogan & Pressley, 1997).

Een belangrijke vraag is echter hoe scaffolding binnen de context van computerondersteund samenwerkend onderzoeken in de klas kan worden opgezet. In de recente onderzoeksliteratuur wordt aangegeven dat scaffolding binnen een technologie-ondersteunde context kan geboden worden door verschillende bronnen die interageren op verschillende sociale niveaus zoals afgebeeld door de cirkels en pijlen op Figuur 2 (Dillenbourg, Järvela, & Fischer, 2009; Kim & Hannafin, 2011). Een eerste bron van ondersteuning tijdens computerondersteund samenwerkend onderzoeken is de technologie. Software-gebaseerde scaffolds kunnen bijvoorbeeld systematisch worden aangeboden in de vorm van prompts die leerlingen stimuleren hun onderzoeksvraag te formuleren en de bronnen kritisch te evalueren (Bannert, 2009; Morris et al., 2010). Een tweede bron van ondersteuning die zich situeert op het groepsniveau, zijn de medeleerlingen aangezien leerlingen samenwerken (Järvelä et al., 2014; Lazonder, 2005). Een derde bron van ondersteuning tenslotte is de leerkracht die zich zowel kan richten tot de volledige klas (buitenste cirkel), tot een bepaald groepje (middelste cirkel) of tot een individuele leerling (binnenste cirkel) (Greiffenhagen, 2012; Makitalo-Siegl et al., 2011; Onrubia & Engel, 2012). Ondanks de beschouwing dat ondersteuning vanuit verschillende bronnen zou moeten vormgegeven worden (Puntambekar & Kolodner, 2005; Tabak, 2004) is onderzoek dat deze verschillende vormen van ondersteuning onder de loep neemt binnen een authentieke context schaars (Kim & Hannafin, 2011).

Figuur 2: Diverse actoren en bronnen van ondersteuning op de drie sociale niveaus die onstaan bij het implementeren van computerondersteund samenwerkend onderzoeken in de authentieke klascontext

Onderzoeksvragen

Bovenstaande probleemanalyse en beschouwingen binnen de literatuur leidden tot drie onderzoeksvragen die dit proefschrift vorm gaven:

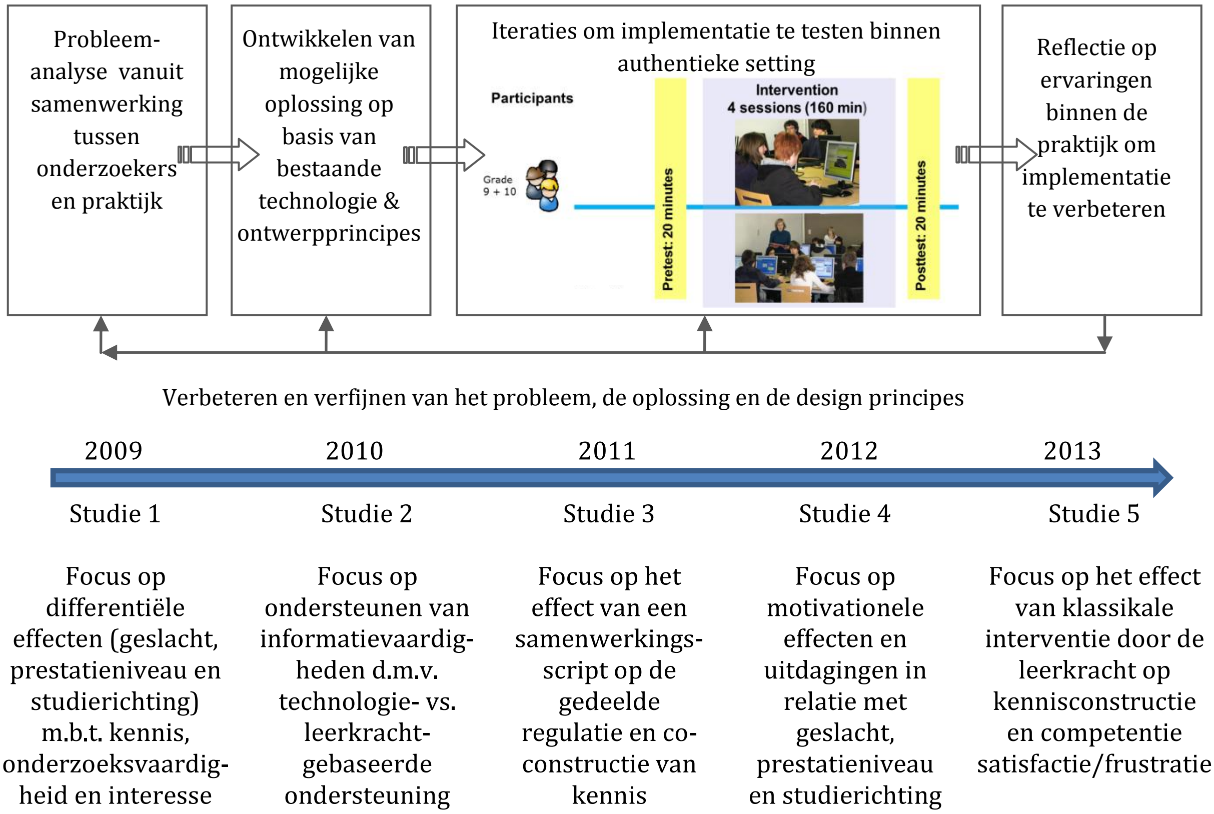
Onderzoeksvraag 1 (OV1): **Wat** is de impact van computerondersteund samenwerkend onderzoeken op kennisverwerving, onderzoeksvaardigheden en motivatie voor wetenschappen?

Onderzoeksvraag 2 (OV2): Voor **wie** is deze werkvorm geschikt en in welke mate beïnvloeden specifieke leerling- en klaskenmerken zoals geslacht, prestatieniveau en studierichting de effectiviteit van de instructie en de specifieke ondersteuningsstrategieën?

Onderzoeksvraag 3 (OV3): **Hoe** moet deze werkvorm in de praktijk worden ingezet en hoe moet ondersteuning vanuit de verschillende bronnen (technologie, medeleerlingen, en leerkracht) worden vormgegeven?

Onderzoekopzet en methodologie

Om op bovenstaande vragen een antwoord te verkrijgen, werd het doctoraatsonderzoek geïnspireerd door de ontwerpgerichte onderzoeksmethode zoals afgebeeld in figuur 3. Deze methodiek heeft namelijk tot doel de onderwijspraktijk te verbeteren door iteratieve analyse, ontwerp, ontwikkeling en implementatie, gebaseerd op een samenwerking tussen onderzoekers en praktijk in een authentieke context (Anderson & Shattuck, 2012; Reeves, 2006). Het WISE-project hierboven beschreven werd gedurende vijf opeenvolgende jaren ingezet tijdens de lessen wetenschappen van leerlingen uit de tweede graad van het secundair onderwijs. De verschillende studies waren allen gelinkt aan bovenstaande onderzoeksvragen, maar hadden elk een andere focus, voortbouwend op de resultaten en de ervaringen uit de voorgaande studie. Vooral met betrekking tot de derde onderzoeksvraag, werden vanuit deze overkoepelde methodologie verschillende opeenvolgende quasi-experimentele studies opgezet waarin de deelnemende klassen willekeurig verdeeld werden over condities die van elkaar verschilden op basis van de aangeboden ondersteuning.



Figuur 3. Overzicht van de vijf interventiestudies geïnspireerd door de ontwerpgerichte onderzoeksmethode (Reeves, 2006)

Deze methodiek impliceert ook dat data verzameld werden op basis van diverse onderzoeksmethoden, zowel kwalitatief als kwantitatief (Cresswell, 2003; Johnson & Onwuegbuzie, 2004). Enerzijds werden (leer)effecten nagegaan aan de hand van pre- en post-testen die afgenomen werden bij de leerlingen voorafgaand en na afloop van het project en peilden naar het niveau van kennisintegratie, de onderzoeksvaardigheid, de regulatievaardigheid en metacognitieve kennis, en de motivatie van jongeren. Anderzijds werden ook kwalitatieve data aan de hand van audio-opnames en observaties verzameld om bijvoorbeeld uitspraken te kunnen doen over de kwaliteit van samenwerking en de mate waarin leerkrachten de ondersteuning correct uitvoerden.

Overzicht en discussie van de hoofdbevindingen

Onderzoeksvraag 1: wat is de impact van computerondersteund samenwerkend onderzoeken op kennisverwerving, onderzoeksvaardigheden en motivatie voor wetenschappen?

- Op basis van de pre– en post-testen afgenomen bij de leerlingen werd vastgesteld dat de niveaus van kennisintegratie omtrent de klimaatverandering significant zijn toegenomen. Dit betekent niet alleen dat de kennis van leerlingen omtrent het thema opwarming van de aarde is toegenomen in vergelijking met de pre-test waarin de antwoorden in meerdere mate incorrect, verwarrend of onvolledig waren. Daarenboven hebben leerlingen duidelijk vooruitgang geboekt in het leggen van correcte en relevante verbanden tussen verschillende wetenschappelijke concepten, oorzaken, gevolgen en verklaringen in de gegeven context en is hun kennis over het topic in mindere mate geïsoleerd. Dit is consistent met voorgaand onderzoek naar WISE die significante leerwinsten rapporteerden door gebruik te maken van computerondersteund samenwerkend onderzoeken (e.g. Lee et al., 2010; Slotta & Linn, 2009).
- Ook de resultaten met betrekking tot de onderzoeksvaardigheden van leerlingen in pre- en post-test wijzen erop dat leerlingen er beter in slagen de onderliggende onderzoeksvraag en hypothesen van een wetenschappelijk onderzoek te genereren. Daarnaast kan het leren met behulp van computerondersteund samenwerkend onderzoeken ook bijdragen tot de informatievaardigheden van jongeren. De voorwaarde is echter dat de opdrachten van bij de aanvang ook toegespitst worden op vergelijken, confronteren, duiden van informatie van uiteenlopende strekking zodat men genoodzaakt is om een diepere analyse van verschillende bronnen uit te voeren en leerlingen aangestuurd worden tot kritische analyse (Wallace, Kupperman, Krajcik, & Soloway, 2000; Kuiper, Volman, & Terwel, 2009). In de eerste studie was dit nog niet het geval en toen werd vastgesteld dat heel wat leerlingen snel overgaan tot knip-en-plak-gedrag en deze “techniek” ook systematisch gebruiken om hun antwoorden in de leeromgeving vorm te geven. De bevindingen bevestigen dat veel jongeren, de zogenaamde “digital natives” niet beschikken over de informatievaardigheden die in heel wat opdrachten verondersteld worden. Het oplossen van een informatieprobleem veronderstelt van leerlingen dat ze in staat zijn om het probleem te definiëren, informatie te zoeken met behulp van de juiste zoektermen, die informatie globaal door te nemen en te beoordelen, vervolgens te verwerken en tenslotte samen te voegen tot een antwoord of te presenteren in bijvoorbeeld een werkstuk (Brand-Gruwel, Wopereis, & Walraven, 2009). Studie 2 en 4 focusten meer specifiek op het ondersteunen van deze vaardigheid en toonden aan dat het leren met behulp van computerondersteund samenwerkend onderzoeken kan tegemoet komen aan de ontwikkeling van deze informatievaardigheden vanuit een hele-taak benadering.

- Met betrekking tot de impact van computerondersteund samenwerkend onderzoeken op de motivatie voor wetenschappen werd in de eerste studie een lichte maar significante stijging vastgesteld voor wat betreft de interesse voor wetenschappen. In studie 4 werd verder ingezoomd op de motivationele effecten van computerondersteund samenwerkend onderzoeken en werd gevonden dat de meerderheid (74%) van de leerlingen nog op deze manier les willen krijgen. Leerlingen apprecieerden voornamelijk de zelfgestuurde en zelfontdekkende manier van leren en gaven aan dat ze meer bijleerden op deze manier, zo blijkt uit volgende citaten *"Ik vind dit veel leuker dan gewoon in de les te zitten en te moeten meevolgen terwijl we hier zelf mogen werken"*, *"Ik vond het leuk om eens op een andere manier les te krijgen en dat je zelf opzoek gaat naar informatie over het onderwerp. Het is ook leuk omdat je ook informatie kunt krijgen uit filmpjes en als je iets niet snapt kan je bv. op een andere website gaan zoeken"*, en *"Ik vond het een goed initiatief zo leren we ook bronnen analyseren en omgaan met de computer, ze vroegen ook vaak ons mening en dat vind ik ook belangrijk. Het is ook een manier om de lessen meer actiever te maken dan zomaar te luisteren, hier zie je het voor je en ben je kritischer."* Toch waren de ervaringen niet eenzijdig positief. Van de 74% gaf 24% aan dat ze enkel onder bepaalde voorwaarden nog les wilden krijgen in de vorm van computerondersteund samenwerkend onderzoeken en een niet verwaarloosbaar deel van de leerlingen (26%) gaf aan niet meer op deze manier les te willen krijgen. De voornaamste reden hiervoor was dat de leerlingen sturing en begeleiding vanwege de leerkracht misten. Ze vonden het vaak moeilijk om zelf het antwoord te zoeken en te formuleren, waardoor frustratie de kop kwam opsteken: *"Ik snap het veel beter als er een persoon dit uitlegt en niet dat we alles zelf moeten opzoeken, want als je iets opzoekt op het net dan kom je heel veel informatie tegen en weet je nooit wat juist en wat niet juist is en als je les krijgt dan kom je dat niet tegen. Ik kan ook de dingen veel beter onthouden van wat er gezegd is geweest in de les".*

Onderzoeksvraag 2: voor wie is deze werkvorm geschikt en in welke mate beïnvloeden specifieke leerling- en klaskenmerken zoals geslacht, prestatieniveau en studierichting de effectiviteit van de instructie en de specifieke ondersteuningsstrategieën?

Vanuit de assumptie dat verschillende instructie- en ondersteuningsstrategieën kunnen verschillen in effect, afhankelijk van individuele leerlingkenmerken, werden deze variabelen in de verschillende studies meegenomen om uitspraken te doen over deze "Aptitude Treatment" interacties (Cronbach & Snow, 1977). De invloed van geslacht, prestatieniveau en studierichting werd zowel nagegaan op de leerwinst in kennisconstructie, de vooruitgang in onderzoeksvaardigheid, strategische kennis en regulatie bij het oplossen van informatievaardigheden, de motivatie voor wetenschappen, als op de evaluatie van de werkvorm.

Met betrekking tot jongens versus meisjes:

- Wat de verschillende impact voor meisjes en jongens betreft, werd geen verschil gevonden in leerwinst en vooruitgang op onderzoeksvaardigheden; jongens en meisjes realiseerden met andere woorden een gelijke leerwinst. Met betrekking tot interesse voor wetenschappen gaven meisjes op de pre-test aan minder interesse te tonen in wetenschap in vergelijking met jongens wat strookt met de algemene bevindingen in de literatuur (Machina & Gokhale, 2010; Taasoobshirazi & Carr, 2008). Na het project was dit verschil in interesse echter niet meer vast te stellen. Dit wil zeggen dat de interesse voor wetenschappen bij jongens gelijk gebleven was, terwijl dit voor meisjes gestegen was zodat het genderverschil dat wel nog vastgesteld werd in de pre-test weggewerkt werd. Deze bevinding is veelbelovend gegeven het feit dat voorgaand onderzoek aantoont dat meisjes vaak benadeeld worden binnen een traditionele instructiecontext omdat jongens meer aangesproken worden om te antwoorden en meisjes bevestigd worden in hun lager zelfbeeld voor wetenschappen (Jones & Wheatley, 1990; Kahle, Parker, Rennie & Riley, 1993). Studie 1 bevestigde de hypothese dat computerondersteund samenwerkend onderzoeken voordelig is voor meisjes omdat de werkvorm onder andere de mogelijkheid biedt om ideeën te bespreken binnen hun groepje wat een veiliger klimaat creëert dan te moeten antwoorden voor de gehele klas.
- In de tweede studie die het effect van technologie-gebaseerde ondersteuning, leerkracht-gebaseerde ondersteuning en de combinatie van beide ondersteuningsstrategieën onderzocht, werd een marginaal significant interactie effect gevonden met betrekking tot geslacht. Terwijl meisjes de grootste leerwinst haalden in de conditie waar de ondersteuningsstrategieën gecombineerd werden, haalden jongens de hoogste leerwinst in de conditie waar enkel leerkracht-gebaseerde ondersteuning geboden werd. Dit resultaat wijst erop dat jongens gevoeliger blijken te zijn voor een "over-scripting effect" wat betekent dat teveel ondersteuning nadelig kan worden (Dillenbourg, 2002). Deze bevinding kan gelinkt worden met een van de resultaten uit de vijfde studie, namelijk dat jongens een significant lagere competentie frustratie ervoeren tijdens computerondersteund samenwerkend onderzoeken in vergelijken met meisjes, wat consistent is met voorgaand onderzoek (Ford, Miller, & Moss, 2001; Liu & Huang, 2008). In de laatste studie die het effect van klassikale momenten binnen computerondersteund samenwerkend onderzoeken onderzocht, werd echter geen effect van geslacht gevonden.
- In de vierde studie werd gevonden dat jongens de werkvorm ook positiever beoordelen dan meisjes. Jongens zijn duidelijk akkoord met de stelling dat leren met WISE een fijne afwisseling is binnen de wetenschapslessen waarbij ze meer gemotiveerd zijn en meer jongens dan meisjes geven ook aan nog op deze manier les te willen krijgen. Dit wil niet zeggen dat meisjes vaker negatief staan tegenover de werkvorm, maar ze gaven wel vaker aan dat ze enkel nog op deze manier wilden lesvolgen onder bepaalde

voorwaarden. Koploper binnen deze voorwaarden is dat deze werkvorm moet afgewisseld worden met klassieke instructie.

Met betrekking tot laag versus hoog presteerders:

- Indien we de leerwinst vergelijken tussen hoog en laag presteerders voor wetenschappen (indeling op basis van de kennisintegratie-pre-test) merkten we dat leerlingen met een zwakker prestatieniveau een significant hogere leerwinst haalden dan leerlingen met een sterker prestatieniveau. Aangezien de hoog presteerders nog steeds niet de hoogst mogelijke score haalden, werd een plafondeffect uitgesloten. Aldus werd de hypothese dat deze werkvorm de minder sterke leerlingen tot een hoger niveau kan tillen bekrachtigd. Dit resultaat kan voornamelijk toegeschreven worden aan het feit dat binnen computerondersteund samenwerkend onderzoeken vanuit een kennisintegratie-benadering de meningen en ideeën van elke leerling erkend worden (Linn & Eylon, 2011).
- Op basis van studie 2 en studie 5 die de effecten van verschillende ondersteuningsstrategieën op de verschillende sociale levels onderzochten, werd een significant interactie-effect gevonden met prestatieniveau. Binnen studie 2 kon geconcludeerd worden dat voornamelijk laag presteerders nood hebben aan begeleiding en ondersteuning door de leerkracht wat overeenkomt met wat in de literatuur beschreven wordt (Kirschner et al., 2006). Hoog presteerders realiseerden daarentegen een even hoge leerwinst zonder de dynamische ondersteuning van de leerkracht als aanvulling op ingebouwde ondersteuning in de digitale leeromgeving, terwijl laagpresteerders die dynamische ondersteuning wel sterk nodig hebben. Binnen studie 5 werd daarenboven gevonden dat laagpresteerders een significant lagere competentie frustratie ervoeren wanneer de leerkracht voorzag in klassikale terugkoppelingsmomenten.

Met betrekking tot wetenschappelijke versus niet-wetenschappelijke richtingen:

- Van de leerlingen die deelnamen aan de verschillende studies kwam de meerderheid telkens uit een wetenschapsklas aangezien leerkrachten sneller bereid waren met zo een klas deel te nemen omdat wetenschapsklassen meer uren wetenschappen hebben en er dus meer tijd kan vrijgemaakt worden voor dergelijke projecten. Dit strookt met de literatuur die erop wijst dat de indeling in studierichtingen ook vaak leidt tot verschillen in kwaliteit van onderwijs (Pickens & Eick, 2009). Binnen wetenschappelijke richtingen wordt er vaker gewerkt aan onderzoeksvaardigheden en hogere-orde denk vaardigheden, terwijl niet-wetenschappelijke richtingen vaak minder uitdagende instructie krijgen (Oakes, 2005). Toch slaagden we erin in elke studie ook telkens enkele klassen uit een niet-wetenschappelijke richting te laten participeren. Op basis van onze data konden we vaststellen dat leerlingen uit een wetenschappelijke richting het significant beter doen dan leerlingen uit een niet-wetenschappelijke richting en dit zowel op de pre-test als op de post-test. Als we echter de leerwinst van beide groepen vergelijken dan merken we dat leerlingen uit niet-wetenschappelijke richtingen een grotere vooruitgang boekten. Deze bevinding werd bevestigd door studie 4 die inzoomde op de motivationele effecten en uitdagingen van computerondersteund samenwerkend onderzoeken. Leerlingen uit een niet-wetenschappelijke richting realiseerden namelijk een significante vooruitgang met betrekking tot de autonome motivatie voor wetenschappen, hoewel dit niet het geval was voor leerlingen uit een wetenschappelijke richting die reeds hoger scoorden met betrekking tot autonome motivatie voor wetenschappen. Daarnaast beoordeelden leerlingen uit niet-wetenschappelijke richtingen de werkvorm ook significant positiever.

Onderzoeksvraag 3: Hoe moet deze werkvorm in de praktijk worden ingezet en hoe moet ondersteuning vanuit de verschillende bronnen (technologie, medeleerlingen, en leerkracht) opgezet worden?

Met betrekking tot de leerkracht als bron van ondersteuning:

- Leerkracht-gebaseerde ondersteuning werd zowel onderzocht op het groepslevel in de vorm van interactie met de verschillende groepjes (studie 2) als op het klassikale level in de vorm van klassikale instructie- en terugkoppelingsmomenten (studie 5). Op basis van de resultaten uit beide studies kan geconcludeerd worden dat leerkracht-gebaseerde ondersteuning op beide niveaus noodzakelijk is om tegemoet te komen aan leerlingen met diverse noden en om zowel kennisconstructie, onderzoekscompetenties, als motivatie voor wetenschappen te ondersteunen. Deze bevindingen bevestigen tevens de hernieuwde aandacht voor de rol van de leerkracht binnen computerondersteund leren (Greifenhagen, 2012; Dillenbourg, Järvelä, & Fischer, 2009; Rutten, van Joolingen, & van der Veen, 2012). Leerlingen, en voornamelijk meisjes, geven aan dat de leerkracht nodig is als begeleider en vakinhoudelijk expert. Ze willen namelijk weten of ze goed bezig zijn, want ze geven aan dat ze vaak niet vertrouwen op het internet.

Met betrekking tot de medeleerlingen als bron van ondersteuning:

- Onderzoek toont aan dat wanneer leerlingen in duo's in een online leeromgeving aan de slag gaan dit zowel op cognitief als sociaal-emotioneel vlak voordelen oplevert in vergelijking met individueel leren (Järvelä et al., 2014; Lazonder, 2005). Het is echter niet zo dat wanneer leerlingen in duo's geplaatst worden, effectief leren en een goede samenwerking gegarandeerd plaatsvindt. Studie 3 ging meer specifiek in op de samenwerking en interactie tussen leerlingen tijdens computerondersteund samenwerkend onderzoeken en ging na of de kwaliteit van samenwerken en meer bepaald de gedeelde regulatie verbeterd kon worden door een "samenwerkingsscript" die een specifieke rolverdeling aangaf (Kobbe et al., 2007). Eén leerling startte het project als de uitvoerder die navigeert binnen de omgeving en het internet en de antwoorden typt, de andere leerling was dan de (web)detective die alert is voor fouten, meedenkt over goede zoektermen en kritisch nagaat of de beste bronnen wel geselecteerd worden. Het "script" ingebouwd in de omgeving gaf aan wanneer leerlingen moesten wisselen van rol.

Er werden echter geen significante verschillen in gedeelde regulatie gevonden die konden toegeschreven worden aan de implementatie van het "samenwerkingsscript". Wel werd de hypothese dat gedeelde regulatie leidt tot betere kennis co-constructie bevestigd (Chiu & Kuo, 2009).

Met betrekking tot technologie als bron van ondersteuning:

- De resultaten van studie 2 toonden aan dat bij alle leerlingen de metacognitieve kennis en regulatie met betrekking tot het oplossen van informatieproblemen vooruit ging na afloop van het project, maar de grootste vooruitgang werd geboekt wanneer leerlingen systematisch de software-gebaseerde prompts aangeboden kregen, al dan niet in combinatie met extra ondersteuning door de leerkracht. Het systematisch aanbieden van procesinformatie die hen waakzaam maakt voor de nodige stappen en aanspoort het gewenste gedrag te stellen, is met andere woorden cruciaal om de strategische kennis en regulatie te verbeteren.

Algemeen besluit

Dit proefschrift ging na welke betekenis computerondersteund samenwerkend onderzoeken kan hebben binnen wetenschapsonderwijs waarin onder invloed van de noden van de 21ste eeuw sterke accentverschuivingen plaatsvonden. Indien we onze leerlingen willen klaarstomen voor een steeds complex wordende arbeidsmarkt moeten naast kennis ook onderzoeksvaardigheden, samenwerkend leren, en de kritische ingesteldheid van jongeren gestimuleerd worden. Daarnaast is een positieve attitude en motivatie voor wetenschappen cruciaal indien we meer jongeren willen warm maken voor wetenschappen. Omdat leerkrachten vaak onder druk staan voor het behalen van de vele leerplandoelstellingen en ze vaak bang zijn dat ze met dergelijke werkvorm tijd zullen verliezen, wordt vaak teruggegrepen naar traditioneel lesgeven. Echter, dit proefschrift benadrukt dat je door middel van computerondersteund samenwerkend onderzoeken zoveel meer kan bijbrengen dan alleen kennis, maar ook kan werken aan samenwerkend leren, onderzoekend leren, en kritisch omgaan met bronnen op het internet. Het WISE project ontwikkeld en geïmplementeerd in de context van dit proefschrift biedt met andere woorden een "good practice" om tegemoet te komen aan de vakoverschrijdende ICT eindtermen en de onderzoekscompetenties binnen de vakcontext wetenschappen. Op basis van de resultaten van dit proefschrift kan tevens geadviseerd worden om deze werkvorm ook meer in te zitten in niet-wetenschappelijke richtingen. Wat betreft de vraag hoe computerondersteund samenwerkend onderzoeken ondersteund moet worden om tegemoet te komen aan de noden van diverse leerlingen binnen een authentieke klascontext kan geconcludeerd worden dat dé beste ondersteuning voor dé leerling niet bestaat. De meest effectieve ondersteuningsstrategie hangt af van de noden van de individuele leerling. Het is met andere woorden belangrijk om te differentiëren en deze werkvorm maakt dit mogelijk aangezien ondersteuning vanuit verschillende bronnen kan worden ingezet. Op die manier heeft de leerkracht de tijd en ruimte om extra aandacht te geven aan leerlingen die dit nodig hebben, terwijl andere leerlingen verder zelfstandig kunnen doorwerken op hun eigen tempo.

Vanuit de beperkingen gerelateerd aan de studies opgenomen binnen dit proefschrift kunnen echter ook aanbevelingen gedaan worden voor toekomstig onderzoek. Hoewel dit proefschrift benadrukt dat ondersteuning moet geboden worden vanuit verschillende bronnen, is verder onderzoek noodzakelijk om te na te gaan hoe de samenhang of “synergie” van de verschillende vormen van ondersteuning binnen een authentieke klassetting gerealiseerd kan worden. Daarnaast is een belangrijke aanbeveling voor zowel de onderwijspraktijk als het onderwijsbeleid om leerkrachten beter op te leiden om onderwijstechnologie als ondersteuning voor het leren en middel om te differentiëren te gebruiken. Dit proefschrift toonde namelijk aan dat binnen computerondersteund leren de leerkracht niet weg te denken is.

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Academic output

Academic output

Output integrated in this dissertation

Journals (A1)

Raes, A., Schellens, T., & De Wever, B. (2014). Web-based Collaborative Inquiry to Bridge Gaps in Secondary Science. *Journal of the Learning Sciences, 23*(3), 316-347. doi: 10.1080/10508406.2013.836656

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Journals (A4)

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Conference papers (P1)

Raes, A., & Schellens, T. (2012). The Impact of Web-based Inquiry in Secondary Science Education on Students' Motivation for Science Learning. In Z. Bekirogullari (Ed.), *Procedia Social and Behavioral Sciences* (Vol. 69, pp. 1332-1339). doi: 10.1016/j.sbspro.2012.12.070

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Raes, A., Schellens, T., De Wever, B., & Vanderhoven, E. (2011, August). *Multiple modes of scaffolding to enhance information problem solving in web-based inquiry.* Paper presented at the European Association for Research of Learning and Instruction (EARLI) Conference, Exeter, UK.

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Raes, A., & Schellens, T. (2013, January). *In search of a synergy between multilevel scaffolding of technology-enhanced inquiry in complex classrooms.* Paper presented at the Alpine Rendez-Vous, Villard-de-Lans, France.

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Yasar, O.,Gobert, J., Toto, E., Margoudi, M., Smyrnaiou, Z., Montrieux, H., Schellens, T., Raes, A., Mäeots, M. & Kori, K. (2014, June). Introducing tablet devices in secondary education: does the teacher matter? In A. Raes (Chair), *Scaffolding Computer-Supported Inquiry Learning*. Symposium conducted at the 18th Conference of the JUnior REsearchers of EARLI, Nicosia, Cyprus.

Raes, A., & Schellens, T. (2014, August). *The effects of teacher-led class interventions during technology-enhanced science inquiry on students' knowledge achievement and basic need satisfaction.* Paper presented at the Earli Conference, SIG 20 Computer-supported inquiry learning, Malmö, Sweden.

Raes, A., & Schellens, T. (2015, April). *Teacher-led Class Interventions can make the Difference in Computer-Supported Collaborative Science Learning.* Accepted for presentation at AERA 2015, Chicago, USA.

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Conference contributions (national) (C1, C3)

Raes, A. (2009, 25 september). Google generatie, feit of mythe? Gepresenteerd op vormingsdag "Zoekstrategieën op internet". VIP Jeugd, Brussel.

Raes, A. (2010, 27 mei). (Onder)zoek(s)vaardigheden van jongeren. Gepresenteerd op studiedag "De Nieuwe Gebruiker". Sectie Schoolbibliotheken van de VVBAD, campus Kantienberg Arteveldehogeschool Gent.

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Raes, A. (2012, 10 maart). Workshop "WISE in de klas". Gepresenteerd op de Dag van Biologie en Natuurwetenschappen. Georganiseerd door de Diocesane Pedagogische Begeleidingsdienst - Bisdom Brugge, KHBO Campus Oostende.

Raes, A. (2014, 15 november). Workshop "Op onderzoek met WISE in de klas". Congres Leraars Wetenschappen, KULAK, Kortrijk.

Data storage facts sheets

% Data Storage Fact Sheet

% Name/identifier study
% Author: Annelies Raes
% Date: June, 5, 2015

1. Contact details
===
1a. Main researcher

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If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies
===
* Reference of the publication in which the datasets are reported:
Raes, A., Schellens, T., & De Wever, B. (2014). Web-based Collaborative Inquiry to Bridge Gaps in Secondary Science. JOURNAL OF THE LEARNING SCIENCES, 23; 316-347. Doi: 10.1080/10508406.2013.836656
* Which datasets in that publication does this sheet apply to?:
This sheet applies to the complete dataset of the study reported in Chapter 2 of the dissertation.

3. Information about the files that have been stored
===
3a. Raw data

The raw data consist of students' individual pre-and post-test data measuring domain-specific knowledge, inquiry skills and interest in science
* Have the raw data been stored by the main researcher? [X] YES / [ ] NO
If NO, please justify:
* On which platform are the raw data stored?
  - [ ] researcher PC
  - [ ] research group file server
  - [X] other (specify): paper version stored in the archive of the department educational sciences

* Who has direct access to the raw data (i.e., without intervention of another person)?
  - [ ] main researcher
  - [ ] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

3b. Other files
----
* Which other files have been stored?
  - [x] file(s) describing the transition from raw data to reported results. Specify: The rubric to score the knowledge test and the rubric to score the inquiry test
  - [x] file(s) containing processed data. Specify: student survey data was processed (i.e. cleaned data in SPSS, aggregated for analysis and restructured for multilevel analysis)
  - [x] file(s) containing analyses. Specify: MLwiN 2.23-generated model outputs (i.e. output of priliminary analyses as well as output of the main analyses regarding the research questions) were stored as .wsz files.
  - [ ] files(s) containing information about informed consent
  - [ ] a file specifying legal and ethical provisions
  - [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
  - [ ] other files. Specify: ...

* On which platform are these other files stored?
  - [x] individual PC
  - [] research group file server
  - [x] other: Research group Mobile Disk for External Data Storage
* Who has direct access to these other files (i.e., without intervention of another person)?
  - [x] main researcher
  - [x] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

4. Reproduction
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* Have the results been reproduced independently?: [ ] YES / [x] NO

* If yes, by whom (add if multiple):
   - name:
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% Data Storage Fact Sheet

% Name/identifier study
% Author: Annelies Raes
% Date: June, 5, 2015

1. Contact details
===
1a. Main researcher

- name: Annelies Raes
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- address: Henri Dunantlaan 2 - 9000 Ghent - Belgium
- e-mail: tammy.schellens@ugent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies
===
* Reference of the publication in which the datasets are reported:
Raes, A., Schellens, T., De Wever, B. &. Vanderhoven, E. (2012). Scaffolding information problem solving in web-based collaborative inquiry learning. COMPUTERS & EDUCATION, 59; 82-94. doi: 10.1016/j.compedu.2011.11.010

* Which datasets in that publication does this sheet apply to?:
This sheet applies to the complete dataset of the study reported in Chapter 3 of the dissertation.

3. Information about the files that have been stored
===
3a. Raw data

The raw data consist of students' individual pre-and post-test data measuring individual learning outcomes. These tests were administerd by the software Limesuvey running on the server of the faculty

* Have the raw data been stored by the main researcher? [X] YES / [ ] NO
If NO, please justify:

* On which platform are the raw data stored?

- [x] researcher PC
- [ ] research group file server
- [x] other (specify): Research group Mobile Disk for External Data Storage

* Who has direct access to the raw data (i.e., without intervention of another person)?
- [x] main researcher
- [ ] responsible ZAP
- [x] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

3b. Other files
----
* Which other files have been stored?
- [x] file(s) describing the transition from raw data to reported results. Specify: The rubric to score the knowledge test and the rubric to score the information problem solving task
- [x] file(s) containing processed data. Specify: student survey data was processed (i.e. cleaned data in SPSS, aggregated for analysis)
- [x] file(s) containing analyses. Specify: SPSS-generated output (i.e. output of priliminary analyses as well as output of the main analyses regarding the research questions) was stored as .spv files.
- [ ] files(s) containing information about informed consent
- [ ] a file specifying legal and ethical provisions
- [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
- [ ] other files. Specify: ...
* On which platform are these other files stored?
- [x] individual PC
- [] research group file server
- [x] other: Research group Mobile Disk for External Data Storage
* Who has direct access to these other files (i.e., without intervention of another person)?
- [x] main researcher
- [x] responsible ZAP
- [x] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

4. Reproduction
===
* Have the results been reproduced independently?: [ ] YES / [x] NO

* If yes, by whom (add if multiple):
- name:
- address:
- affiliation:
- e-mail:

% Data Storage Fact Sheet

% Name/identifier study
% Author: Annelies Raes
% Date: June, 5, 2015

1. Contact details
==
1a. Main researcher

- name: Annelies Raes
- address: Henri Dunantlaan 2 - 9000 Ghent - Belgium
- e-mail: annelies.raes@ugent.be

1b. Responsible Staff Member (ZAP)

- name: Tammy Schellens (Supervisor PhD Project)
- address: Henri Dunantlaan 2 - 9000 Ghent - Belgium
- e-mail: tammy.schellens@ugent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies
==
* Reference of the publication in which the datasets are reported:
Raes, A., Schellens, T., & De Wever, B. (Submitted). Promoting Shared Regulation during Joint Information Problem Solving on the Web. Manuscript submitted for publication in International Journal of Computer-Supported Collaborative Learning

* Which datasets in that publication does this sheet apply to?:
This sheet applies to the complete dataset of the study reported in Chapter 4 of the dissertation.

3. Information about the files that have been stored
==
3a. Raw data

The raw data consist of students' individual pre-and post-test data measuring individual learning outcomes, group performances, audiodata of the recorded group interactions and observation logbooks
The pre- and post-tests were administerd by the software Limesuvey running on the server of the faculty.
* Have the raw data been stored by the main researcher? [X] YES / [ ] NO
If NO, please justify:

* On which platform are the raw data stored?
  - [x] researcher PC
  - [ ] research group file server
  - [X] other (specify): Research group Mobile Disk for External Data Storage
* Who has direct access to the raw data (i.e., without intervention of another person)?
  - [x] main researcher
  - [ ] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

3b. Other files
----
* Which other files have been stored?
  - [x] file(s) describing the transition from raw data to reported results. Specify: The rubrics to score the indivual learning outcomes, and the rating schemes of the quality of collaboration per recorded dyad
  - [x] file(s) containing processed data. Specify: student survey data was processed (i.e. cleaned data in SPSS, aggregated for analysis and restructured for multilevel analysis using MLwiN)
  - [x] file(s) containing analyses. Specify: all MLwiN 2.23-generated model outputs (i.e. output of priliminary analyses as well as output of the main analyses regarding the research questions) were stored as .wsz files.
  - [ ] files(s) containing information about informed consent
  - [ ] a file specifying legal and ethical provisions
  - [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
  - [ ] other files. Specify: ...
* On which platform are these other files stored?
  - [x] individual PC
  - [] research group file server
  - [x] other: Research group Mobile Disk for External Data Storage
* Who has direct access to these other files (i.e., without intervention of another person)?
  - [x] main researcher
  - [x] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

4. Reproduction
===
* Have the results been reproduced independently?: [ ] YES / [x] NO
* If yes, by whom (add if multiple):
   - name:
   - address:
   - affiliation:
   - e-mail:

% Data Storage Fact Sheet

% Name/identifier study
% Author: Annelies Raes
% Date: June, 5, 2015

1. Contact details
===
1a. Main researcher

- name: Annelies Raes
- address: Henri Dunantlaan 2 - 9000 Ghent - Belgium
- e-mail: annelies.raes@ugent.be

1b. Responsible Staff Member (ZAP)

- name: Tammy Schellens (Supervisor PhD Project)
- address: Henri Dunantlaan 2 - 9000 Ghent - Belgium
- e-mail: tammy.schellens@ugent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies
===
* Reference of the publication in which the datasets are reported:
Raes, A. & Schellens, T. (2015). Unraveling the motivational effects and challenges of web-based collaborative inquiry learning across different groups of learners. EDUCATIONAL TECHNOLOGY RESEARCH & DEVELOPMENT, 63; 405-430. doi: 10.1007/s11423-015-9381-x

* Which datasets in that publication does this sheet apply to?:
This sheet applies to the complete dataset of the study reported in Chapter 5 of the dissertation.

3. Information about the files that have been stored
===
3a. Raw data

The raw data consist of students' individual pre-and post-test data measuring individual learning outcomes, group performances, and the answers on an open ended evaluation question
The pre- and post-tests were administerd by the software Limesuvey running on the server of the faculty:
* Have the raw data been stored by the main researcher? [X] YES / [ ] NO
If NO, please justify:

* On which platform are the raw data stored?
  - [x] researcher PC
  - [ ] research group file server
  - [X] other (specify): Research group Mobile Disk for External Data Storage
* Who has direct access to the raw data (i.e., without intervention of another person)?
  - [x] main researcher
  - [ ] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

3b. Other files
----
* Which other files have been stored?
  - [x] file(s) describing the transition from raw data to reported results. Specify: The rubrics to score the indivual learning outcomes, and the generated categories after content analysis
  - [x] file(s) containing processed data. Specify: student survey data was processed (i.e. cleaned data in SPSS, aggregated for analysis and restructured for multilevel analysis using MLwiN)
  - [x] file(s) containing analyses. Specify: all MLwiN 2.23-generated model outputs (i.e. output of priliminary analyses as well as output of the main analyses regarding the research questions) were stored as .wsz files. The spss outputs of the chi-square tests were stored as .spv files.
  - [ ] files(s) containing information about informed consent
  - [ ] a file specifying legal and ethical provisions
 - [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
  - [ ] other files. Specify: ...
* On which platform are these other files stored?
  - [x] individual PC
  - [] research group file server
  - [x] other: Research group Mobile Disk for External Data Storage
* Who has direct access to these other files (i.e., without intervention of another person)?
  - [x] main researcher
  - [x] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

4. Reproduction
===
* Have the results been reproduced independently?: [ ] YES / [x] NO
* If yes, by whom (add if multiple):
   - name:
   - address:
   - affiliation:
   - e-mail:

% Data Storage Fact Sheet

% Name/identifier study
% Author: Annelies Raes
% Date: June, 5, 2015

1. Contact details
==
1a. Main researcher

- name: Annelies Raes
- address: Henri Dunantlaan 2 - 9000 Ghent - Belgium
- e-mail: annelies.raes@ugent.be

1b. Responsible Staff Member (ZAP)

- name: Tammy Schellens (Supervisor PhD Project)
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- e-mail: tammy.schellens@ugent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies
==
* Reference of the publication in which the datasets are reported:
Raes, A. & Schellens, T. (Submitted). The effects of teacher-led class interventions during technology-enhanced science inquiry on students' knowledge integration and basic need satisfaction. Manuscript submitted for publication in Computers & Education.

* Which datasets in that publication does this sheet apply to?:
This sheet applies to the complete dataset of the study reported in Chapter 6 of the dissertation.

3. Information about the files that have been stored
==
3a. Raw data

The raw data consist of students' individual pre-and post-test data measuring individual learning outcomes, group performances, detailed logbooks per classroom involved in the intervention study, video recordings. The pre- and post-tests were administerd by the software Limesuvey running on the server of the faculty.
* Have the raw data been stored by the main researcher? [X] YES / [ ] NO
If NO, please justify:

* On which platform are the raw data stored?
  - [x] researcher PC
  - [ ] research group file server
  - [X] other (specify): Research group Mobile Disk for External Data Storage
* Who has direct access to the raw data (i.e., without intervention of another person)?
  - [x] main researcher
  - [ ] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

3b. Other files
----
* Which other files have been stored?
  - [x] file(s) describing the transition from raw data to reported results. Specify: The rubrics to score the indivual learning outcomes
  - [x] file(s) containing processed data. Specify: student survey data was processed (i.e. cleaned data in SPSS, aggregated for analysis and restructured for multilevel analysis using MLwiN)
  - [x] file(s) containing analyses. Specify: all MLwiN 2.23-generated model outputs (i.e. output of priliminary analyses as well as output of the main analyses regarding the research questions) were stored as .wsz files.
  - [ ] files(s) containing information about informed consent
  - [ ] a file specifying legal and ethical provisions
  - [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
  - [ ] other files. Specify: ...
* On which platform are these other files stored?
  - [x] individual PC
  - [] research group file server
  - [x] other: Research group Mobile Disk for External Data Storage
* Who has direct access to these other files (i.e., without intervention of another person)?
  - [x] main researcher
  - [x] responsible ZAP
  - [x] all members of the research group
  - [ ] all members of UGent
  - [ ] other (specify): ...

4. Reproduction
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* If yes, by whom (add if multiple):
   - name:
   - address:
   - affiliation:
   - e-mail: