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Web-based Collaborative Inquiry to Bridge Gaps in Secondary Science Education

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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.

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 15 to 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; Organisation 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 number 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 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 and 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 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 use for informal learning, and they are often required to consume, complete, and replicate given knowledge (d'Apollonia, 2010). In addition, it is a paradox that, especially among girls, low-achieving science students and students from a general track (i.e., students without a focus on science in their curriculum) are often deprived of engaging in science instruction because of stereotypical beliefs and a self-fulfilling prophecy (explained further later). This results in a higher likelihood of these students considering science as boring, difficult, and irrelevant to 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 students of 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 information and communication technology, 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 the 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 & VRWB, 2008), and despite the merits of this learning approach revealed by educational research (Bennett, Lubben, & Hogarth, 2007; Krajcik et al., 1998; Mistler-Jackson & Songer, 2000; Slotta & Linn, 2009), its 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 science students 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. We wonder whether there are differences in (learning) gains with regard to knowledge acquisition, inquiry skills, and interest in science that 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 complexity that results when several factors interact, we present the quantitative evidence by means of hierarchical linear modeling in order to add to previous research in this area, which has 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 there is steady growth in the number of female students enrolling in university and higher education (Machina & Gokhale, 2010; Meulders, Plasman, & Rigo, 2009), females are still underrepresented in faculties of sciences (Taasobshirazi & 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 & VRWB, 2008). The fact that girls and boys often experience qualitatively different educational situations because of 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 these students 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 that consist of a package of courses focusing on languages, economics, and/or science. Dividing students into different academic tracks occurs primarily on the basis of students' 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 variety of students, one can ask 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) stated 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, referred 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 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 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 (H. S. Lee, Linn, Varma, & Liu, 2010; Linn, Lee, Tinker, Husic, & Chiu, 2006). 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).

Regarding the second objective, 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 integrated understanding about science topics but also students' ideas about scientific methods and the image of experimentation that students acquire. Linn and Eylon (2011) stated 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 communication 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 (M. K. Lee & Erdogan, 2007; Slotta & Linn, 2009).

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

With regard to *gender*, it has been found that although some research has 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 have 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 e-mail or real-time communication programs (Leong & Hawamdeh, 1999). An in-depth case study by Mayer-Smith, Pedretti, and Woodrow (2000) found that women 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 attitudes 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 because of the use of computers and the Internet. Moreover, we propose that girls can even benefit from this kind of science learning because of having 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 previously, it has been found that *general-track students* and *low-achieving science students* are often deprived of instruction emphasizing scientific reasoning and inquiry-based instruction because of 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 they do not give other students the chance to actually benefit from this type of inquiry (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 science students (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 for 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 mentioned one study in which students who scored below and above the median on the pretest were compared and found that these students 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 because of 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 although 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 while students participated 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 of this learning approach 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: (a) 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; (b) the research project implements Web-based collaborative inquiry in a variety of *authentic science classrooms*; and (c) 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 through 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 science students, as the knowledge integration approach respects the ideas of all learners and gives all students the chance to express their thoughts while 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 that 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 (WISE) from the University of California at Berkeley was developed along the lines of the knowledge integration approach. This was 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

FIGURE 1 The Web-based Inquiry Science Environment. On the left is a screenshot of the teacher's portal. On the right is a screenshot of the students' portal (color figure available online).

the inquiry map on the left side that 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, and engaging in reflection and self-assessments. During a WISE project, students work in pairs, and all of their teamwork is stored in a database that is accessible to teachers and researchers for the purposes of assessment.

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 Flemish educational practice. The new WISE curriculum project was designed in partnership with science teachers and technology specialists based on the codesign 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 because of uncertainty and controversy in the scientific community regarding the scientific issues associated with climate change, it can be considered a complex topic. Moreover, students often struggle with the underlying scientific phenomena, including energy transfer from the sun to the earth, the greenhouse effect, and the role of the 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 in this process.

Based on the knowledge integration approach previously described, Slotta and 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, and Promote autonomy. Moreover, the design of the activities is based on the following instructional pattern: Elicit ideas, Add new ideas, Distinguish among ideas, and 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
Examples of Project Activities in the Global Climate Change Project

<i>KI Instructional Pattern</i>				
<i>KI Principle</i>	<i>Elicit Ideas</i>	<i>Add New Ideas</i>	<i>Distinguish Among Ideas</i>	<i>Reflect on and Integrate Ideas</i>
Making science accessible to all students	Generate ideas/hypotheses about students' personal impact on global climate change.	Calculate students' own ecological footprint on the WWF website.	Compare students' ecological footprint to others'.	Reflect about humanity's demands on nature and how to reduce the impact on the earth.
Making thinking visible	Generate hypotheses about differential impact among wealthy and poor countries.	Analyze CO ₂ 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 one another	Brainstorm to be prepared for online classroom debate between believers and nonbelievers.	Search for evidence for human activities or natural processes that cause climate change.	Compare 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 students' own science knowledge.	Generate, read, listen to, or observe ideas/evidence.	Critique and validate Internet evidence on the strengths and weaknesses.	Connect evidence from the Web with personal understanding.

Note. Examples are based on the knowledge integration (KI) approach (Slotta & Linn, 2009).

Participants

To study the differential effects of Web-based collaborative inquiry on different types of students, we implemented the global climate change curriculum project in authentic classrooms as illustrated in Figure 2. A request for participation in this project was distributed via e-mail to the principals of the secondary schools in two provinces in Flanders. In the e-mail, 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 was involved in the research project, each with one or two of their classes, and each agreed to devote four 50-min 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% followed a general track and 78% followed 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

FIGURE 2 The pretest/posttest design to study the implementation of the Web-based inquiry science project in authentic classrooms (color figure available online).

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 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 8 classes supported by three Master's students each and 11 classes supported by two Master's students each.

Design and Procedure

By means of a quasi-experimental pretest/posttest 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 pretest. Afterward, 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 posttest. The students whose pre- or posttest was missing because of absence from this particular lesson were excluded from the data set. Therefore, 356 students remained for data analysis.

Dependent Variables and Measures

The dependent variables in this study were students' domain-specific knowledge, inquiry skills, and interest in science, all measured on an individual basis in the pretest and posttest. The following instruments were used: (a) a pre- and post-achievement test to investigate knowledge acquisition and the acquisition of inquiry skills and (b) 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 were 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 13 assessment items: 8 items were open-ended knowledge questions scored on a rubric from 0 to 3, whereas the remaining 5 items asked students to first answer a multiple-choice question and then explain the scientific idea behind their answer (this explanation was scored on a rubric from 0 to 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 (2010) community that rewarded both accurate and connected ideas. The rubrics displayed in Appendixes 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 to form a score for knowledge acquisition (minimum = 0, maximum = 44).

The next part of the achievement test aimed to measure students' *science inquiry skills*. In a pre- and posttest, 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: (a) Is the underlying research question clearly formulated? (score 0–2), (b) Are the two hypotheses correctly and clearly recited? (score 0–2), (c) Are the participants in the proposed research clearly formulated? (score 0–2), (d) Is the treatment that needs to be tested clearly formulated? (score 0–2), and (e) 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 (minimum = 0, maximum = 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 interrater 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 interrater agreement (Hayes & Krippendorff, 2007).

In order to assess students' *interest in science*, we used one scale from the science assessment of the PISA study (OECD, 2007). 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 included nine items requiring students to express their level of agreement on a 5-point Likert scale with statements expressing interest in science. Cronbach's alphas for the interest in science scale were .91 for the pretest and .92 for the posttest, which are acceptable reliability coefficients (Nunnally, 1978).

Multilevel Analysis

Given the design, the present study focused on individual pretest/posttest comparisons across existing groups. Nevertheless, as the students worked together in small groups and these groups originated from existing classes, the problem under investigation had a clear hierarchical structure. In this respect, the analysis of test data at an individual level raises a methodological issue that 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 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 pretest/posttest design used in this study, our data analysis encompassed repeated measures on individuals over time. The test time was then added as a dummy variable (0 = pretest or T0, 1 = posttest or T1). Consequently, a four-level structure arose: Both test times (Level 1) were clustered within students (Level 2), which were nested within dyads (Level 3), which in turn were 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 pretest score of the student's 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 that served as a baseline model. This unconditional null model without any predictor variables provided both the overall pretest score and the overall learning gain for all students across all groups and classes. Moreover, by means of intraclass correlation, the model answered the question of whether the outcome measures varied 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 allowed cross-level interactions to be detected between student and class characteristics. This resulted in Model 1, which provided 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 previously are presented in Table 2. As we used a repeated measures approach, our conceptual unconditional null model (Model 0) predicted the overall knowledge score on the pretest 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 posttest 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 gave rise to two residuals as shown in the random part of the model: one for pretest and one for learning gain. The null model divided the variance of the pretest scores as well as the variance of the learning gain into between-classes, between-dyads, and between-students components. The total variance of the pretest scores was 48.92, which was 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 calculating the intraclass correlation, which revealed the correlation of the observations (cases) within each cluster on the different levels, we can state that 36.03% of total pretest variance lay at the class level, the proportion of variance due to differences between dyads was 24.46%, and finally 39.51% of the total variance lay at the student level. As depicted in Table 2, these

TABLE 2
Multilevel Parameter Estimates for the Four-Level Analyses of Students' Knowledge Acquisition

<i>Parameter</i>	<i>Model 0</i>	<i>Model 1</i>
Fixed parameters		
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 $\times$ Low		0.89 (0.84)
Girl $\times$ General Track		1.43 (1.27)
Low $\times$ General Track		1.49 (1.38)
Girl $\times$ Low $\times$ General Track		-4.31* (1.79)
Girl $\times$ Learning Gain		1.22 (0.82)
Low $\times$ Learning Gain		5.65*** (0.83)
General Track $\times$ Learning Gain		5.33* (2.53)
Girl $\times$ Low $\times$ Learning Gain		0.73 (1.15)
Girl $\times$ General Track $\times$ Learning Gain		-5.3** (1.73)
Low $\times$ General Track $\times$ Learning Gain		-2.60 (1.86)
Girl $\times$ Low $\times$ General Track $\times$ Learning Gain		5.78* (2.43)
Random parameters		
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 $\times$ log likelihood (deviance)	4,282.38	3,939.89
χ^2		342.49
<i>df</i>		14
<i>p</i>		<.001
Reference model		Model 0

Note. Standard errors are in parentheses.

* $p < .05$. ** $p < .01$. *** $p < .001$.

variances in pretest scores on the three levels were significantly different from zero at the $p < .001$ level. With respect to the variance in learning gain, we also found significant variances at the three levels. The total variance consisted of 34.43% between-class variance, 20.42% between-dyad variance, and 45.15% between-student variance.

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 ($\chi^2 = 342.49$, $df = 14$, $p < .001$). 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 pretest (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 posttest score of 25.6.

The results presented in Model 1 indicate that no significant main effects were found regarding gender with respect to both pretest scores and learning gain in knowledge. This means that overall, boys and girls do not differ significantly with respect to knowledge pretest scores or learning gain scores. Achievement level and academic track, however, are significant predictors of pretest scores and of learning gain scores. On the one hand, low-achieving students and students following a general track scored significantly lower on the

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 posttest score.

pretest 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 overall knowledge performance, some interaction effects were found. Based on the significant three-way interaction of Girl $\times$ Low Achiever $\times$ General Track, we can state that although female low achievers from the general track started the project with significantly lower pretest scores (7.7), they achieved the highest learning gains (17.9), bringing their posttest score to a level that is closer to that of other groups. As can be 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 were composed might have influenced 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 ($\chi^2 = 5.35$, $df = 8$, $p < .71$), 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 indicated that the overall scientific inquiry level on pretest was 5.89 out of 10. Students' overall improvement in inquiry skills was 1.36, which was found to be significant ($\chi^2 = 10.64$, $df = 1$, $p < .01$). The random part, however, indicated that the variances on the class, dyad, and student level were significantly different from zero regarding the residuals for pretest scores. The total variance in students' pretest inquiry performance consisted of 29.61% at the class level, 13.97% at the dyad level, and 54.52% at

the student level. Regarding students' improvement in inquiry skills, no significant variance was found at the group level, but the total variance consisted 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 ($\chi^2 = 7.78$, $df = 14$, $p = .90$). 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 in their inquiry skills. The same was true when we added 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' pretest level of interest in science and their potential gains in interest. The fixed part of the four-level null model indicated that the overall interest in science prior to the intervention was 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 ($\chi^2 = 4.21$, $df = 1$, $p < .05$) in interest in science was found. Based on the random part of the null model, we know that the variance in interest in science prior to the intervention amounted to 22.05% at the class level, 17.77% at the dyad level, and 60.17% at the student level, which were all significantly different from zero at the $p < .05$ level. The variance in the gain scores for interest in science, however, was only found at the student level.

By adding the independent variables, we found only significant main effects that resulted in a significant improvement of the model fit ($\chi^2 = 22.29$, $df = 6$, $p < .05$), 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 was significantly lower than that reported by boys. However, we also found a significant main effect for gender regarding improvement in 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 reported an

TABLE 3
Multilevel Parameter Estimates for the Four-Level Analyses of Students' Interest in Science

<i>Parameter</i>	<i>Model 0</i>	<i>Model 1</i>
Fixed parameters		
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 $\times$ Gain in Interest		0.12** (0.04)
Low $\times$ Gain in Interest		0.01 (0.04)
General Track $\times$ Gain in Interest		0.01 (0.05)
Random parameters		
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		
$-2 \times \log$ likelihood (deviance)	802.49	780.20
χ^2		22.29
<i>df</i>		6
<i>p</i>		<.05
Reference model		Model 0

Note. Standard errors are in parentheses.

* $p < .05$. ** $p < .01$. *** $p < .001$.

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 posttest score.

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 number 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 Web content in which they are interested. Moreover, science education faces the challenging task of providing adequate instruction to meet the needs of a variety 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 underrepresented in science, which might be related to the fact that girls and boys often experience qualitatively different educational situations because of stereotypical beliefs related to science as a male domain (Greenfield, 1996). Second, low achievers in science are disadvantaged because, because of teachers’ self-fulfilling prophecy, they are often deprived of engaging instruction that 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 these students 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 students of 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, research with a focus on the potential benefits of this learning approach for these disadvantaged science groups 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 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 could 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 could also benefit low-achieving science students, 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 would be suitable and beneficial for science-track as well as general-track students, as it can counter the prominent self-fulfilling prophecy described earlier. Whereas most previous studies only included one factor in isolation, for instance gender, without taking into consideration the complexity that arises when these different factors interact, this study tested the main and interaction effects of the predictor variables at the student, dyad, and class level by means of a multilevel approach. Multilevel models were built to analyze the effects of the Web-based inquiry project on three desired outcomes, 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 conceptual knowledge across all students. This is consistent with previous research showing significant pretest to posttest gains in learning science by means of Web-based inquiry learning (e.g., H. S. 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 pretest 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 pretest, and no significant difference was found in their learning gain. However, a significant three-way interaction, that is, Girl $\times$

Low Achiever $\times$ General Track, was found on the pretest 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 pretest 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 that can elicit these achievement boosts.

The higher learning gains for disadvantaged students might possibly be explained by the integrated design principles that promote knowledge integration (Bell & Linn, 2000). It seems that lower achieving students in particular 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 discussing them 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 science students. 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 or 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) that 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 cooperative 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 for 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. Whereas the study by Leong and Hawamdeh 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 identification of the research question, hypothesis generation, and planning of an investigation. Students' scores on the inquiry test improved significantly. Nevertheless, no significant effects were found regarding the variables gender, achievement level, and academic track, meaning that there was 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. What is interesting is that a slight but significant 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 posttest. 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 has been 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

One 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 could definitely be attributed to the Web-based collaborative inquiry in science education. Besides this, it would have allowed us to test aptitude treatment interactions, a concept that is based on the assumption that some instructional strategies (treatments) are more or less effective for particular individuals depending upon the individuals' specific abilities (Cronbach & Snow,

1977). Another limitation is related to the fact that 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 time and facility available 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 CSCL 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. Researchers need to investigate Web-based inquiry learning for more extended periods of time and across different science topics. In this respect, professional development is needed to enable teachers to integrate these classroom strategies—that is, collaboration, inquiry, and technology-enhanced learning—into their everyday science teaching. 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: (a) 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; (b) the research project implemented Web-based collaborative inquiry in an authentic science classroom; and (c) 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 not only that implementing a Web-based collaborative inquiry project in science education using a knowledge integration approach is an effective approach for science learning but also that this instructional approach can particularly benefit disadvantaged science students who are not typically successful in science or not enrolled in a science track. It was 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 science students 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 that 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.

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APPENDIX A

Example 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? Think about the right answer and explain your answer. The sun The cosmos The atmosphere

Figure A

Figure B

APPENDIX B

Scoring Rubric for Knowledge Items

<i>Grade/Score</i>	<i>Response Description</i>
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 correctly and coherently as a token of a systematic understanding.

APPENDIX C

Scoring Rubric for Explanation Items

<i>Grade/Score</i>	<i>Response Description</i>
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.