

The impact of web-based collaborative inquiry for science learning in secondary education

Annelies Raes, Tammy Schellens, Bram De Wever, Department of Educational Studies, Ghent University,
Henri Dunantlaan 2, 9000 Ghent,

Email: annelies.raes@ugent.be, tammy.schellens@ugent.be, bram.dewever@ugent.be

Abstract: Current educational practice in higher education shows a growing use of CSCL-environments. In secondary education, however, we only see the first signs of transformation in the age of technology and the Internet, and many of these signs are particularly at the administrative level rather than in the classroom. Nevertheless, research, as well as national standards, support collaborative learning and the integration of ICT as an answer to the decreased interest and motivation in science learning and the growing importance that is attached to inquiry skills. This research project deals with the use of web-based collaborative inquiry as a promising approach for secondary science education. In particular, this study investigated the impact of the implementation of a Web-based Inquiry Science Environment (WISE) on students' content knowledge, their inquiry skills and their attitude and engagement towards science. An empirical study in 19 secondary science classes was conducted and 375 students were involved. Additionally, this study focused on gender differences and highlighted the transformation of the teachers' role in web-based teaching. The present study demonstrates the effectiveness of this innovative instructional approach in the attempt of making science accessible and interesting to all and to rectify the gender imbalance in science education.

Introduction

The latest Eurobarometer on "Young People and Science" (2008), investigating the public's opinion, revealed that young Europeans (aged between 15 and 25) have a positive view about science and technology. However, when presented with several choices of scientific study, only a minority of these young people said they were considering them. These findings are in line with the first results of PISA 2006. The PISA results reveal that Flanders belongs to the group of OECD countries which achieved very high results for scientific literacy. On the other hand, in comparison with the 15-year-old students in the average OECD country, fewer Flemish students reported that they are motivated to learn science, and only an absolute minority thought that they will work with science later on (De Meyer, 2008). The number of students who consider taking up studies and careers in science is at a low level. This is especially true for female students. Recent research findings emanating from a range of countries demonstrate that gender equity in science education is still a cause for concern. One of the reasons for this gender differentiation in science interest is the perception shared by many girls that only boys or men are good in science and technology (Sedeno, Balmaseda, Suarez, & Dauder, 2008). Nevertheless, different research findings demonstrate that during elementary education girls' scientific achievement is equal to boys' achievement. However, in secondary education, boys significantly outperform girls with respect to science (TIMSS, 2003; PISA, 2006). The number of girls that graduate in a scientific, mathematic or technical master is lower than the number of boys. Moreover, according to the Flemish board for scientific policy (2008), this number is still decreasing.

Concerns are raised about this lack of interest in science, and the resulting reduction in the numbers of young people who opt to study science subjects at an advanced level. These concerns seem justified, especially in an industrialized society. In addition to potential economic and labor market consequences of this disinterest, there are also social and cultural consequences, since science represents an important part of the culture in which an understanding of scientific phenomena is required to participate fully in many topical debates (Woodgate & Stanton Fraser, 2007). One of the reasons for young people's lack of interest in science is that much of what goes on in science classrooms is not particularly attractive to students (Stark and Gray, 1999; Flemish governmental enquiry, 2005).

Next to that, National standards stress the growing importance that is attached to inquiry skills. More particularly, enhancing student's understanding of science concepts and process skills rather than merely teaching the lower textual-level scientific knowledge is a major goal for science educators (Galili, 1996).

These findings stress the review, rethink, and reform of science education to make science accessible and interesting to all and to rectify the gender imbalance in science education. In this respect, we investigated the impact of web-based collaborative inquiry as an innovative instructional approach for science learning in Flemish secondary education.

Theoretical and Empirical Framework

Inquiry-oriented science instruction has been characterized in a variety of ways over the years (Collins, 1986; DeBoer, 1991; Rakow, 1986) and promoted from a variety of perspectives. 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. According to constructivist models, learning is the result of ongoing changes in our mental frameworks as we attempt to make meaning out of our experiences (Osborne & Freyberg, 1985).

Inquiry-based programs have been found to generally enhance student performance related to scientific literacy and understanding of science processes (Lindberg, 1990), conceptual understanding (Slotta & Linn, 2009) and positive attitudes toward science (Kyle et al., 1985; Rakow, 1986). Moreover, research shows clearly that by reflecting, applying ideas, and collaborating with peers, students develop a sense of the relevance of science (Bransford, Brown, & Cocking, 1999). Research confirms the commonly held view that collaborative learning motivates students (Gillies, 2003) and there is evidence for the fact that students develop a positive attitude towards the course in which collaborative learning is applied (Stevens & Slavin, 1995; Nichols & Miller, 1994; Nichols, 1996; Springer, Stanne & Donovan, 1999).

With the growing importance of the World Wide Web, this information resource can serve as a means for collaborative inquiry that opens the boundaries of the classroom and creates the possibility for students to pursue questions of personal interest (Wallace, Kupperman, Krajcik, & Soloway, 2000). Research on Computer Supported Collaborative Learning (CSCL) has contributed to the claim that collaborative activity among students can effectively be supported with computer technology (Lou, Abrami, & d'Apollonia, 2001). In this respect, web-based collaborative inquiry is a promising approach. National standards and policy advisors confirm this and call for inquiry learning and the integration of technology into science classes.

In higher education, we are now witnessing a slow but steady growth in the use of CSCL, where student activities and student-teacher exchanges are coordinated through online environments. In primary and secondary education, however, we only see the first signs of transformation in the age of the Internet, and many of these signs are particularly at the administrative level rather than in the classroom (Cox, Abbott, Webb, Blakeley, Beauchamp, & Rhodes, 2004; Tondeur, van Braak, & Valcke, 2007). Apparently, teachers prefer conservative, rather than revolutionary applications of technology. Teachers remain predominantly focused on lectures and textbooks, using the Internet primarily as a supplemental resource for Web searches or multimedia materials (Slotta, 2004). Nevertheless, in research institutions technology-based environments for (collaborative) inquiry learning have been developed, such as WISE (Slotta, 2004), Co-LAB (van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005) or BGuILE (Reiser, Tabak, Sandoval, Smith, Steinmuller, & Leone, 2001) as an arguably, more interesting and motivational approach to secondary science education.

Although different technology-based environments for collaborative inquiry learning have been developed, little large-scale research has been conducted with regard to the benefits of this approach. Through an intervention study we investigated the impact of a web-based collaborative inquiry project on content knowledge, inquiry skills and attitude and engagement towards science.

Research questions

Four major research questions drove this study:

1. What is the impact of the web-based collaborative inquiry project on students' understanding of scientific phenomena?
2. What is the impact of web-based collaborative inquiry on students' inquiry skills, particularly hypothesis generation?
3. What is the impact of web-based collaborative inquiry on students' attitude and engagement towards science?
4. Is there a differential impact for gender?

Additionally, this study wanted to investigate web-based collaborative inquiry from the teachers' point of view with the aim of exploring how the changed classroom activity created by being online and involved in an inquiry project affected the work of teaching.

Research design and Method

Participants

The participants in this study were 375 students from 19 secondary school classes (grade 9, 10, and 11, the average age of these students was 16 years). The ratio of males to females in the participants was 54% girls to

46% boys. The classes were selected from 15 Flemish secondary schools and a group of 17 science teachers were involved in the research project. Teacher participation in the intervention was voluntary and teachers agreed to dedicate 4 lessons of 50 minutes to implement the CSCL-project.

Procedure and design

Forty-six master students Educational Sciences were involved in this study to support the implementation of the project and to conduct the questionnaires and tests. For these students, this assignment was a formal part of the 7-credit course Educational Technology at Ghent University. The 46 master students were divided over the 19 classes participating in this study. There were several reasons for designing the study in this way. First, the classroom teachers did not have the time to go through a training period and the interventions had to be carried out according to a set of instructional principles. Second, the master students had more expertise in the theoretical backgrounds of CSCL and were more prepared and familiar with the inquiry-based learning environment. Third, master students acted as a researcher as well. After a specific training, master students were responsible for data collection through a semi-structured interview, pre- and posttests, and observations during the sessions.

The inquiry-based learning environment used in this study was the Web-Based Inquiry Science Environment (WISE). WISE is developed to provide a solid technology platform that allows teachers to adopt new forms of inquiry-based instruction (Slotta & Linn, 2009). Based on Peters & Slotta (2009) a Flemish WISE-curriculum project was co-designed in partnership with science teachers and technology specialists. The project addressed global warming and climate change and was connected to the standards-based curricula in secondary education. The intervention was developed taking into account research-based design principles promoting knowledge integration and scientific inquiry.

During the first session, secondary students completed the individual pretest and were introduced to WISE. Depending on the time left, they also started in dyads the first activity of the project. The total project consisted of four main activities. Students worked in the same dyads during the whole intervention and navigated through the sequence of inquiry activities using the inquiry map in the WISE environment. During the project, students were asked to write their answers down in reflection notes. Consequently, all of their project work was stored in a database, which was accessible to teachers and researchers for purposes of assessment. Finally, all students completed the individual posttest.

During the sessions, master students were asked to act as a “leader from the within” instead of a “guide on the side”. A “leader from the within” does not only monitor students but actively engage the students, helps them to synthesize their views, and maintains a dynamic process of exchange within the classroom (Slotta & Linn, 2009). After each session master students provided electronic, both positive and critical, feedback through the feedback tool of WISE.

Data Collection, Instruments and Analysis

In this study data was collected using a mixed method approach.

First, a pretest-posttest design was used to assess the impact of the intervention. The test consisted of three main parts which assessed content knowledge, the ability to do scientific inquiry, and the attitude and engagement towards science. In the first part, thirteen assessment items were developed to measure content knowledge, eight of them were knowledge/multiple-choice items and five of them were explanation items that went beyond reproducing knowledge and asked students to connect ideas in arguments. The latter items were scored using the knowledge integration rubric that rewards both accurate and connected ideas, created by TELS. This rubric contains a number of proficiency levels. The higher the proficiency level, the more complex the skills that the students have to master to tackle the scientific problems. In the second part, students were asked to read a research article and to generate the underlying hypotheses and research questions. In order to assess students' attitude and engagement towards science, in the third part, three scales of the international PISA (2006) questionnaire were used: support for science, interest in science and responsibility towards resources and environments. Response options consisted of a 5-point Likert scale.

Second, data was obtained through content analysis of all students' reflection notes during the four successive science lessons and the additional observation reports made by the master students.

Finally, after completing the project, semi-structured interviews of the classrooms teachers were conducted to assess their acceptance and attitude towards the innovative environment and approach. Furthermore, focus groups were organized twice with the master students to reflect on their experiences with the organization and implementation of the web-based sessions. Special emphasis was put on their role as a teacher in a web-based collaborative project.

Data analyses were conducted using the software program SPSS, version 15.0. Paired sample t-tests, independent sample t-tests and analysis of variances were conducted to determine the impact of the intervention.

Results

General results

Based on the observations and focus groups, we found that master students had difficulties to perform as a “leader from the within”. Most of the time they monitored the way students were progressing and mainly responded to any confusion, in this way they acted generally as a “guide on the side”. They were quite occupied managing the technology and monitoring students. Secondary school students who did not ask for help or did not have obvious technical problems that required help, were not stimulated to do more. Master students asked on a regular base how students were doing but when these students responded positive, no follow up questions were asked.

Regarding the classroom teachers, all of them were positive about this experience. They were especially pleased to have their students learn in a web-based collaborative inquiry environment and are willing to participate in future research.

Content knowledge, inquiry skill and attitude and engagement towards science

Based on the pre- and posttest items we can determine that, overall, there is significant improvement in terms of knowledge and explanation. As shown in Table 1, students made progress in connecting ideas in arguments (explanation items) and their active knowledge (content knowledge items) about climate change has increased. In the pretest the numbers of incorrect and irrelevant answers were significant higher and knowledge about the topic was rather isolated.

Table 1: Average item mean, average item standard deviation, and differences (effect size and t-test for paired samples) between pretest and posttest using the individual as the unit of analysis

Different scales	Pretest		Posttest		Difference	
	M	SD	M	SD	ES	T (df)
Content knowledge items	1.38	0.57	2.23	0.44	1.6	27.97 (364)**
Explanation items	1.70	0.68	2.62	0.66	1.36	23.93 (365)**
Inquiry skill	1.8	1.03	2.17	0.82	0.41	6.49 (357)**
Support for science	3.69	0.43	3.68	0.48		-0.237 (327)
Interest in science	3.43	0.68	3.47	0.67	0.05	2.02 (314)*
Responsibility towards resources and environments	4.07	0.48	4.13	0.49	0.12	2.95 (305)**

* $p < 0.05$ ** $p < 0.01$

N=375

The results for the second part of the test where students were asked to deal with a research article are also significantly higher. Students became better in generating the underlying research questions and hypotheses in a research article. However, the qualitative data based on the reflection notes and observation reports force us to refine this result. We observed frequent use of the ‘copy and paste’ function, so that text fragments from the internet were directly included in their answers. Furthermore, students tend to reduce the whole task to finding an obvious answer on a particular website while less attention was paid to understanding the content and critical thinking.

With regard to the impact on attitude and engagement towards science, the results are less consistent. Concerning the support for science, we noticed that this is quite high at the pretest (3.6 on 5-point-likert), however no significant differences can be found compared to the posttest. However, the other two attitude scales (interest in science and responsibility towards resources and environments) do show significant differences between the pre- and the posttest although the effect sizes are low.

Gender differences

Boys and girls do not score significantly different on the knowledge part of the pretest. In contrast, the scores on the posttest do significantly differ. Girls outperformed boys on knowledge items ($t = 3.09$, $df = 367$, $p < .01$) as

well as on explanation items ($t = 4.32$, $df = 368$, $p < .01$). In other words, girls benefited more than boys from the intervention. With respect to inquiry skills, no significant gender differences can be revealed.

With regard to the attitude towards science, no significant gender differences are found concerning the *support for science*, this in contrast to the *interest in science* and the *responsibility towards resources and environments* where significant gender differences are revealed. Girls had a significant lower interest in science on the pretest, but this difference disappeared after the intervention. Regarding the responsibility towards resources and environments, we can observe the same trend as in the knowledge part. Boys and girls do not score significantly different on the pretest, but in the posttest girls were more positive than boys on this attitude scale ($t = -2.36$, $df = 269$, $p = .02$).

Discussion and conclusion

This study aimed to get students engaged with science content through inquiry and action. More specifically, this study dealt with the use and impact of web-based collaborative inquiry as a promising approach for secondary science education on students' understanding of scientific phenomena, their inquiry skills, and their attitude and engagement towards science. In addition, this study examined gender differences.

The present study demonstrated the effectiveness of web-based collaborative inquiry. This effectiveness is especially shown for girls. On the posttest, girls outperformed boys on knowledge items, explanation items, and responsibility towards resources and environments. This implies that this innovative instructional approach is an effective contribution in the attempt of making science accessible and interesting to all and to rectify the gender imbalance in science education (TIMMS, 2003; PISA, 2006). Overall, after the intervention, students made significant gains in understanding standards-based science concepts and improved on the inquiry test. Yet, we can conclude that information seeking as a part of an inquiry-based learning environment seems to be a complex and difficult progress for these students. During the web-based inquiry project students were faced with information problems, tasks that require them to identify information needs, locate corresponding information sources, extract and organize relevant information from each source, and synthesize information from a variety of sources (Brand-Gruwel, Wopereis, & Vermetten, 2005). It is often assumed that students naturally master this complex cognitive skill of information problem solving. According to this study, this assumption can be countered. According to previous research, we know that metacognitive knowledge and awareness is critical for students to be able to control and regulate their information problem-solving processes (Lazonder, 2003). However, little is known so far about effective instruction in information problem solving. Further research planned in March 2010 will provide insight into effective scaffolds to support student-directed inquiry. Furthermore, future research needs to focus on what teachers can do in an online classroom to effectively support student learning at more than a merely technical level, given that CSCL works best if the teacher interacts with the students and maintains a dynamic process of exchange within the classroom (Slotta & Linn, 2009). Unfortunately, our findings show that most of the time, the teachers acted mainly as a "guide on the side".

References

- Brand-Gruwel, S., Wopereis, I., & Vermetten, Y. (2005). Information problem solving by experts and novices: analysis of a complex cognitive skill. Paper presented at the AERA 2003 Symposium, Chicago, IL.
- Bransford, J. D., Brown, A.L., & Cocking, R. (1999). How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy Press.
- Collins, A. (1986). A sample dialogue based on a theory of inquiry teaching (Tech. Rep. No. 367). Cambridge, MA: Bolt, Beranek, and Newman
- Cox, M., Abbott, C., Webb, M., Blakely, B., Beauchamp, T., & Rhodes, V. (2004). ICT and pedagogy: a review of the research literature. ICT in Schools Research and Evaluation Series, 18. London: DfES/BECTA.
- DeBoer, G. E. (1991). A history of ideas in science education. New York: Teachers College Press.
- De Meyer, I. (2008). Science competencies for the future in Flanders. The first results from PISA 2006. Ghent: OECD.
- European Commission.(2008). Flash Eurobarometer: Young people and science: analytical report, from http://ec.europa.eu/public_opinion/flash/fl_239_en.pdf
- Flemish Governmental enquiry (2005). Say what you want...about sciences, from http://ewi-vlaanderen.be/documenten/rapport_resultaten_enquete.pdf
- Galili, I. (1996). Students' conceptual change in geometrical optics. *International Journal of Science Education*, 18, 847-869.
- Gillies, R.M. (2003). Structuring cooperative group work in classrooms. *International Journal of Educational Research*, 39, 35-49.
- Kyle, W. C., Jr., et al. (1985). What research says: Science through discovery: students love it. *Science and Children*, 23(2), 39-41.

- Lazonder, A. W. (2003). Principles for designing web searching instruction. *Education and Information Technologies*, 8, 179-193.
- Lindberg, D. H. (1990). What goes 'round comes 'round doing science. *Childhood Education*, 67(2), 79-81.
- Lou, Y., Abrami, P.C., & d'Appolonia, S. (2001). Small group and individual learning with technology: a meta-analysis. *Review of Educational Research*, 71(3), 449-521.
- Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., & Chrostowski, S.J. (2004), Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.
- Nichols, J.D. & Miller, R.B. (1994). Cooperative Learning and Student Motivation. *Contemporary Educational Psychology*, 19, 167-178.
- Nichols, J.D. (1996). The Effects of Cooperative Learning on Student Achievement and Motivation in a High School Geometry Class. *Contemporary Educational Psychology*, 21, 467-476.
- Osborne, M., & Freyberg, P. (1985). *Learning in science: Implications of children's knowledge*. Auckland, New Zealand: Heinemann.
- Peters, V. L., & Slotta, J. D. (2009). *Co-designing curricula to promote collaborative knowledge construction in secondary school science*. Proceedings of the 9th international conference on Computer supported collaborative learning - Volume 1, Rhodes, Greece.
- Rakow, S. J. (1986). Teaching science as inquiry. Fastback 246. Bloomington, IN: Phi Delta Kappa Educational Foundation.
- Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F., & Leone, A. J. (2001). BGuiLE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In S. M. Carver & D. Klahr (Eds.), *Cognition and instruction: Twenty-five years of progress* (pp. 263-305). Mahwah, NJ: Erlbaum.
- Sedeno, E. P., Balmaseda, I. S., Suarez, M. J. M., & Dauder, S. G. (2008). Perception of Science and Technology in teenage students from Madrid. *Arbor-Ciencia Pensamiento Y Cultura*, 184(733), 949-966.
- Slotta, J. D. (2004). Web-Based Inquiry Science Environment. In M. C. Linn, E. A. Davis & P. Bell (Eds.). *Internet Environments for Science Education* (pp. 203-231). Mahwah, NJ: Lawrence Erlbaum Associates.
- Slotta, J. D., & Linn, M. (2009). *WISE Science: Web-Based Inquiry in the Classroom*. New York: Teachers College Press.
- Springer, L., Stanne, M. & Donovan, S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research*, 69, 21-51.
- Stark, R., & Gray, D. (1999). Gender preferences in learning science. *International Journal of Science Education*, 21(6), 633-643.
- Stevens, R.J. & Slavin, R.E. (1995). The Cooperative Elementary School: Effects on Students' Achievement, Attitudes and Social Relations. *American Educational Research Journal*, 32, 321-352.
- Tondeur, J., van Braak, J., & Valcke, M. (2007). Towards a typology of computer use in primary education. *Journal for Computer Assisted Learning*, 23(3), 197-206.
- van Joolingen, W. R., de Jong, T., Lazonder, A. W., Savelsbergh, E., & Manlove, S. (2005). Co-Lab: Research and development of an on-line learning environment for collaborative scientific discovery learning. *Computers in Human Behavior*, 21, 671-688.
- Wallace, R. M., Kupperman, J., Krajcik, J., & Soloway, E. (2000). Science on the web: Students online in a sixth-grade classroom. *Journal of the Learning Sciences*, 9(1), 75-104.
- Woodgate, D. & Stanton Fraser, D. (2007). Workshop of Emerging Technologies for Inquiry-Based Learning in Science. Supplementary Proceedings of the 13th International Conference of Artificial Intelligence in Education, from <http://aied.inf.ed.ac.uk/AIED2007/InquiryBasedLearning.pdf>