This is a draft version for: Pifarré, M. & Argelagós, E. (2008). Inquiry Web-Based Learning to Enhance Information Problem Solving Competences in Science. In J. Zumbach, N. Schwartz, T. Seufert & L. Kester. *Beyond knowledge: the legacy of competence. Meaningful Computer-Based Learning Environments* (pp. 153-162). United Kingdom: Springer.

INQUIRY WEB-BASED LEARNING TO ENHANCE INFORMATION PROBLEM SOLVING COMPETENCE IN SCIENCE.

Manoli Pifarré & Esther Argelagós

Universitat de Lleida (UdL), Spain.

Author note

Manoli Pifarré, Department of Pedagogy and Psychology, Faculty of Science Education, University of Lleida, Avda. Estudi General, 4, 25001 Lleida. E-mail: pifarre@pip.udl.cat, Telephone number: 00 34 973 70 65 61, Fax number: 00 34 973 70 65 02.

Esther Argelagós, Department of Pedagogy and Psychology, Faculty of Science Education, University of Lleida, Avda. Estudi General, 4, 25001 Lleida. E-mail: eargelagos@pip.udl.cat, Telephone number: 00 34 973 70 66 19, Fax number: 00 34 973 70 65 02

Abstract

Early research on using web information indicates that secondary students fail to explore much web tools, use them naively and have serious difficulties to understand and integrate web information. In response to these challenges, the main goal of this research has been to design, implement and evaluate an instructional approach that helps students learn from web information. We have developed on-line learning materials which focus on specific curricular contents and provide specific scaffolds to help students accomplish web-based tasks and develop specific information problem-solving competencies. These scaffolds have intended to give support to students involved in information-seeking activities as they were asked questions, searched for information, organised and assessed their findings, and created rich representations of their newly-constructed understandings. We have designed a one year long study to investigate the depth and accuracy of 127 secondary students, as regards their content understanding as well as their development of information problem-solving competencies when using on-line resources to solve instructional tasks. Our research demonstrates that the experimental group performed computer-based activities statistically better than the control group. Our findings also suggest that students were able to develop accurate and in-depth understanding from web information if they could appropriately use search and managerial strategies. This research lends evidence to questions regarding the value of students engaging in on-line inquiry web-based learning to enhance content understanding and to develop more efficient information problem-solving competencies in secondary education.

Introduction

Educational research highlights the potential of the World Wide Web (WWW) as an instructional tool for classrooms. Since the Internet can change the nature of learning, it is important to highlight its potential by increasing access to instructional materials in a variety of media, promoting students' skills in information gathering and problem solving, encouraging network collaborations, and having access to decentralized resources (e.g. Ryder & Graves, 1997; Hoffman, Wu, Krajcik & Soloway, 2003). In short, the Internet offers education a window of opportunity to augment traditional methods and teaching and learning materials and strategies.

Focusing on science learning, several researchers (Oliver-Hoyo, Allen & Anderson, 2004; Prince & Felder, 2006) state that inquiry learning has been frequently found to be more effective than traditional science instruction at improving academic performance, development of thinking, problem-solving, and laboratory skills.

Many studies have introduced the use of World Wide Web resources in the inquiry process: in Inquiry Based Learning (henceforth, IBL), students conduct science research as practicing scientists do. In Science class, IBL helps learners get involved with diverse ideas and knowledge integration and make connections between their existing ideas, information, observations, and diverse perspectives with the goal of developing more coherent and generative scientific knowledge (Lim, 2004; Martinello & Cook, 2000).

Science educators agree that the use of WWW resources in classrooms as well as the use of IBL activities have a positive effect on learning science. However, the implementation of web resources to support IBL has some complexities that should be considered. Some literature has highlighted that users often get lost very easily on the Internet when looking for information and users have many difficulties selecting the right information from a large variety of sources of information (Navarro-Prieto, Scaife & Rogers, 1999). Research also indicates that students experience certain difficulties in regulating their learning when they use hypermedia environments to learn about complex topics (Azevedo, Cromley & Seibert, 2004; Brush & Saye, 2001).

All the skills, knowledge and attitudes needed to carry out the different electronic information activities can be defined as information problem solving (henceforth, IPS). Research concerning the process of IPS proposes various theoretical models to represent the cognitive processes involved in carrying out a web-based activity. Our frame of reference is based on the Big6™-model (Eisenberg & Berkowitz, 1990) that distinguishes six phases or general skills: task definition, information-seeking strategies, location and access, use of information, synthesis and evaluation.

Several research studies reveal that students fail to master IPS skills all by themselves (for example: Lazonder, 2000; Guinee, Eagleton & Hall, 2003), which suggests that attention should be paid to the design, implementation and evaluation of explicit, intensive and effective instruction.

In response to this educational necessity, our work offers more insight into the challenge of combining information and communication technology with IBL and procedural guidance in order to increase the students' involvement and responsibility in their own learning of complex science topics. The study described in this paper is aimed at helping the scientific education community move toward extending the notion of designing and implementing scaffolding in web-based activities. With this in mind, an instructional approach to help students search and understand web information and learn from the web was designed, implemented and evaluated during one academic year with secondary education students. On-line learning materials focusing on specific curricular science-based contents and specific scaffolds to help students accomplish web-based tasks and construct their knowledge were designed by our research group. The effect of students' participation on the IBL instructional process was analyzed on the basis of the students' web information competences and outcomes.

Research questions

One of the main research objectives was to study how to address some of the complexities of researching network learning in secondary education. This was approached by designing, implementing and evaluating a web-based instructional process which uses web resources to develop, support and improve the students' IPS skills and to promote content understanding. In this line of work, this research pivots around three research questions:

1. Does the web-based instructional process have any impact on the students' learning results?
2. What depth and accuracy of content understanding do learners demonstrate when they answer web-based activities?
3. Which IPS skills are enhanced by the web-based instructional process?

Method

Participants

A total of 127 secondary education students participated in the study. The students came from two secondary education levels (2nd year -13/14 years old- and 4th year -15/16 years old) and from three different middle-class urban schools in Lleida (Spain).

Students were randomly distributed in two different groups: experimental and control group. In the experimental group, students followed the web-based instructional process during one academic year. The control group studied the same curricular contents as experimental students with the standard teaching methodology. Both groups (control and experimental) took a pre-test (Mars activity) and a post-test (Moon activity).

Procedure

The experimental process consisted of three phases: pre-test, intervention (only for the experimental group) and post-test.

Pre-test / Post-test

Two equivalent computer-based activities (pre and post-test) were designed in order to evaluate secondary students' performance in the process of searching, selecting, integrating and using web information to solve a curricular task. The pre-test activity focused on planet Mars and the post-test activity focused on the Moon. Both contents were new for the students participating in this study.

The pre-test and post-test activities consisted in three different types of task whose main difference laid on the degree of complexity. The students' answers to these activities were saved in a server, scored and analysed. Besides, the students' computer screen actions while solving the tasks were captured using screen cam software (CamStudio 2.0).

Intervention: The web-based learning environment

The Intervention phase was different for the control and experimental groups. The control group studied the same science-based curricular contents as the experimental group, and occasionally used the Internet as an additional educational resource following teacher criteria.

The experimental group was engaged in a one year-long web-based instructional project and consisted in 3 WebQuests activity projects (12 intervention hours). According to Dodge (1995) a WebQuest is an inquiry-oriented activity in which some or all of the information that learners interact with comes from resources on the internet. These activities were solved in pairs and focused on curricular science contents.

With the purpose of promoting the students' IPS skills in learning complex science topics in a meaningful way, web-based instructional materials were designed for this project. Scientific IBL, scaffolding, and knowledge construction were key concepts that guided the activity design process, which was divided into four interrelated instructional components:

a) Designing and structuring web-based activities aimed at decomposing the complex cognitive procedure of IPS in critical sub-skills that let students gain competence in solving web information tasks (Land & Greene, 2000; Eisenberg & Berkowitz, 2000). The web-based activities give guidance and specific scaffolds to learn skills in the main IPS stages, namely 1) defining the information problem, 2) searching information, 3) locating and accessing information, 4) processing information 5) synthesising, organizing and presenting information and 6) evaluating results. Three studies were taken as reference to design the pedagogical structure of the web-based activities: Dodge (1995); Lim (2004); Steel, Kelsey & Morita (2004).

b) Promoting inquiry web learning. An important aspect of inquiry and critical condition towards developing conceptual understanding is the generation of explanations and theories for the phenomena at hand (Perkins, Crismond, Simmons & Unger, 1995; Scardamalia & Bereiter, 1994). In the computer-based activities of our project, information seeking and web information understanding were presented as problems in which students were immersed in a learning environment and those problems were designed to support question-asking, resource gathering and the construction of new knowledge.

c) Scaffolding to support the learning process. This study viewed scaffolding as a process of providing decreasing amounts of support to help students bridge the gap between their current abilities and the intended goal of instruction that allows students to participate at ever-increasing levels of competence (Rosenshine & Meister, 1992). Scaffolding materials appear in our work in the form of procedural guidelines that support the students' problem-solving process. These scaffolded instructions allowed students to gain appropriate experience and skills that increased their cognitive capabilities toward the task.

c) Enriching the students' information problem solving skills. In all the web-based activities, selected and essential skills to solve science-related information problems were used. To be specific, the following computer-based activities were employed: 1) Students were enrolled in the search process, thereby enriching their knowledge about the search engines and their search skills. 2) The web-based activities scaffolded the development of strategies to select and elaborate web information such as tables of contents, taking personal notes and synthesis information. 3) Special attention was paid to strategies to organise web information for learning purposes such as: conceptual maps, schemes and graphics. 4) In all the activities students had to submit a personal product with content-rich activities as reports, summaries, and presentations, which were also scaffolded 5) the development of regulation skills for the coordination of the process of IPS were stressed in all the activities such as: task analysis, decision-making skills to fulfil the activity and evaluation questions to help students test both the process and the product.

Data analyses and results

In order to answer the three research questions, data analyses combined the study of both quantitative and qualitative data.

Regarding quantitative data as a means to answer the first research question of our study, i.e. does the web-based instructional process have any impact on students' learning results?, the degree of correctness of the students' answers to the different questions in the pre-test and post-test activities was analysed. Students' responses were scored in a binary fashion as being either correct (1) or incorrect (0). Control and experimental groups were statistically equivalent at the beginning of the intervention. The pre-test means were statistically equivalent by a significance level of 95% (independent *t*-test: $t(125)=1.325$; $p=0.187$). From the 21 maximum points that could be obtained in the test, the experimental group scored $M=12.15$ $SD=3.41$; and the control group scored $M=13.01$ $SD=3.33$.

The post-test means were statistically different (independent *t*-test: $t(125)=-2.38$; $p=0.019$). Experimental students outperformed their counterparts in the control group (the maximum points to obtain in the test were 21; experimental group $M=12.99$ $SD=3.36$; control group $M=11.53$ $SD=2.77$). These data show that the instructional approach followed by the experimental group had a positive incidence on the students' web performance.

Regarding qualitative data as a means to answer our second research question of study, i.e. what depth and accuracy of content understanding do learners demonstrate when they answer the web-based activities?, the pre-test and post-test final product was analysed in terms of quality of content understanding. Content understanding was viewed not only as a collection of facts and definitions within a particular subject area, but as the utilization of mapping schemes to associate concepts with benchmarks and strategies for memorization and recall.

In order to analyse the nature and quality of the knowledge produced by students, the *mean level of explanation* was analysed across students' productions. Each content idea constructed by students to answer the main activity question was classified using a four-step scale starting from two categories related to description of facts: (1) separate pieces of facts and (2) organised facts; followed by two categories related to explanation: (3) partial explanation and (4) explanation (Hakkarainen, 2003; Perkins, Crismond, Simmons & Unger, 1995).

Control and experimental groups were statistically equivalent at the beginning of the intervention in the variable "Mean level of explanation" (Pearson Chi-Square $\chi^2=5.79$; $p=0.216$). Statistical differences were found between two groups in the post-test results ($\chi^2=25.32$; $p=0.000$).

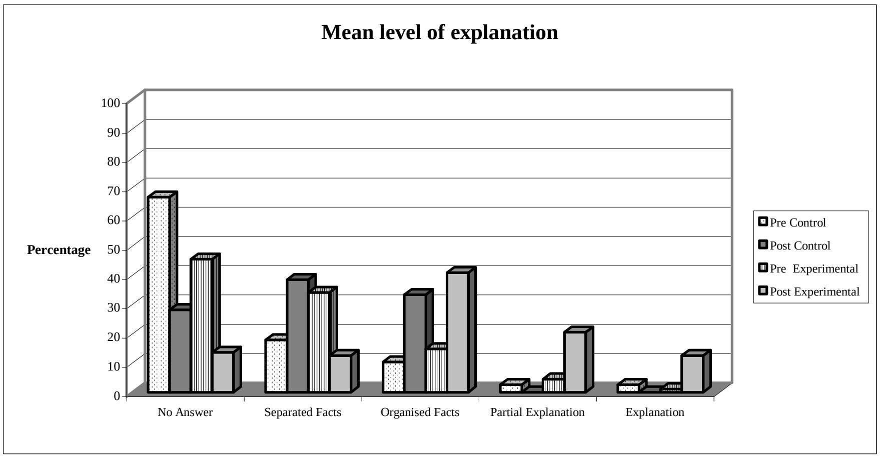

Figure1. Percentages of each category of the variable "Mean level of explanation".

Figure 1 displays the percentages of each category of the variable "Mean level of explanation". In the pre-test, both groups showed a considerable amount of null answers and answers without any kind of explanation (see "Separate facts"). By contrast, the post-test of the experimental group indicated a change in their actions. In the answers in which students made an effort to elaborate personal explanations, articulated relationships and extended explanations increased significantly. These results show that experimental students could benefit from access to on-line resources when extensive support and scaffolding were provided. These findings are similar to those obtained in other studies. In this line, Hoffman, Wu, Krajcik & Soloway (2003) describe how students move to high levels of content understanding and learning when they interact and learn from an on-line learning environment designed to support question asking, resource gathering and the construction of new understandings.

To answer the third question of our study, i.e. which searching and managerial competencies are enhanced by the web-based instructional process?, case-study methodology was used. Three students in their second year of secondary education (13/14 years old) (one of the control group –a girl– and two students of the experimental group –a boy and a girl) were randomly selected and screen cam software (CamStudio 2.0) recorded their computer actions while solving pre- and post-test activities. The sessions were transcribed and analysed. The final transcriptions registered then both the actions done on the computer screen by students as well as the time spent.

An inductive-deductive method was used both to develop the coding system that analyzed the computer screen actions and to evaluate the use of specific IPS skills. Though no thinking-aloud methodology was used in this research, the search strategy employed could be deduced from the student's actions on the computer screen, particularly search patterns.

The Big6^{TM}-model (Eisenberg & Berkowitz, 1990) and three other studies were taken as reference to define the coding scheme: Brand-Gruwel, Woperis &

Vermetten (2005); Lanzoder (2000) and Pejtersen & Fidel (1999). The scoring system consisted of two levels of categories geared to study and describe the use of specific IPS skills and analyse the possible changes and improvements in the use of these skills after students' participation in the web-based instructional process.

In the first level of categories the four main skills of IPS to solve the specific curricular task of our study were defined, namely: defining the problem and task analyses; searching information process; processing information and organising and presenting information. The four main skills were scored in an exclusive way. In the second level of categories, each main skill was refined into several sub skills or constituent elements of the main skill. In figure 2 the skill decomposition is shown.

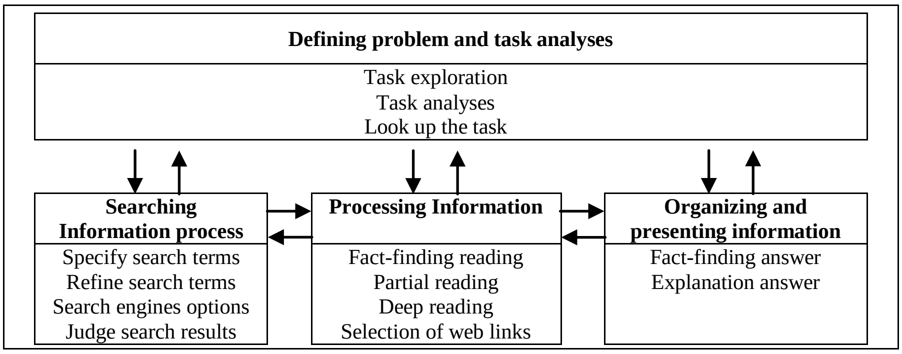

Figure 2. Skill decomposition of the IPS skill used in our study.

Though metacognition skills are assumed as important in IPS process, in this study we have not considered them as a specific category. However, we are planning to carry out an in-depth study and analysis of metacognition skills from our data and transcriptions.

The analysis of time invested in solving the activity shows some differences in the three cases. Experimental students devoted more time to solve the whole activity in the post-test than in the pre-test. In contrast, the control student revealed a different pattern, she needed less time to solve the post-test activity than in the pre-test (table 1). These data may suggest that experimental students used more complex information problem-solving skills to solve the post-test.

Pre Control	Post Control	Pre Exp. 1	Post Exp. 1	Pre Exp. 2	Post Exp. 2
30.5	17.7	20.1	23.4	38.2	40.1

Table 1. Time invested in solving the activity (in minutes).

When analysing the frequency of use of the four main skills of IPS to solve the pre-test and post-test activities of our study, remarkable differences could be found between the three cases. In the post-test, experimental students increased the skills used to analyse the task and search information and decreased the number of times that they processed web information in relation to the pre-test. In contrast, the control student showed a similar use of these skills in the pre-test and post-test activity. The value of defining the problem and analysing the task is underlined in IPS literature and is associated with effective and efficient problem solving (Hill, 1999; Lazonder, 2000).

Particularly interesting in this study is the increase of sub-skills related to in-depth web information analysis. In the post-test activity, experimental students showed that their processing of the web information was more profound than that of the control group student, in that they could read the task-related information better, they could search more adequate terms and could select web pages that were more appropriate to the information they searched. Problem-solving literature emphasizes the incidence of task analysis when solving any task adequately (Land & Greene, 2000).

In addition, significant differences between control and experimental students were obtained regarding search information sub-skills. Experimental students developed more elaborate skills such as using appropriate search terms, using the different options of the search engines and using correct search results in order to find the information to solve the task (table 2). These findings are in agreement with those obtained in studies analysing differences in expert and novices in IPS tasks, which indicates that experts use more efficiently searching information skills (Lazonder, 2000).

	Pre Control	Post Control	Pre Exp. 1	Post Exp. 1	Pre Exp. 2	Post Exp. 2
Defining problem and Task analyses	**34.13**	**23.88**	**24.49**	**22.22**	**17.52**	**23.51**
Deep	19.16	14.93	5.10	17.46	12.39	12.75
Superficial	2.99	7.46	1.02	3.17	1.71	1.20
Searching information	**15.57**	**16.42**	**10.2**	**20.63**	**20.09**	**40.64**
Search terms	6.59	8.21	5.10	8.73	7.26	15.54
Correct judgement of search results	4.79	2.24	1.02	5.56	5.56	10.76
Wrong judgement of search results	1.8	2.24	5.1	3.97	2.14	2.79
Processing information	**45.51**	**46.27**	**63.27**	**46.03**	**45.73**	**25.1**
Correct reading	28.14	30.6	10.2	23.81	33.33	19.12
Wrong reading	7.78	10.45	12.24	13.49	5.56	2.39
Correct selection of links	1.80	2.24	5.10	3.97	2.14	2.79
Wrong selection of links	1.80	0.75	13.27	0.00	1.28	0.00
Organizing and presenting information	**4.79**	**13.43**	**2.04**	**11.11**	**16.67**	**10.76**

Table 2.Number of times that main skills and some sub-skills are performed by the three case-students (in percentage).

Discussion and conclusions

Our research has developed, implemented and evaluated an instructional environment to integrate the World Wide Web as a learning tool in the secondary education curriculum. The results obtained verify better quantitative results in the post-test by the experimental group whose intervention approach enhances the students' development of more efficient searching and managerial web-information strategies and better content understanding.

Comparing the qualitative results, namely, a) level of explanation of the students' productions and b) use of IPS skills, we determined that they coincided with each other. After participating in the web-based instructional process, experimental students increased the use of skills related to a more thorough examination of web information and the construction of new understandings. Therefore, the findings of our work suggest that students can benefit from access to on-line resources when both extensive support and scaffolding in IPS skills are provided.

However, the qualitative results reveal that the most frequent types of students' explanation involve facts –separate and well-organised facts- and partial explanation. The analysis of the post-test students' written productions provides a slight and yet promising, increases in the quality of the student's content understanding.

Although the experimental group outperformed the control group, differences were not relevant enough to generalise our findings. The conclusions drawn in this work present a positive and promising path in the design of instructional processes to enhance students' digital literacy which, in turn, improves the student's content understanding using web information.

Acknowledgements

This research was totally funded by the Spanish National Plan of R+D (projects number BSO2003-05409 and SEJ2006-12110). We would also like to express our gratefulness to the teachers and secondary students who participated in this study.

References

Azevedo, R., Cromley, J.G., & Seibert, D. (2004). "The role of self-regulated learning in fostering students' conceptual understanding of complex systems with hypermedia". *Journal of Educational Computing Research*, 30(1), 87-111.

Brand-Gruwel, S. Wopereis, I. & Vermetten, Y. (2005). "Information problem solving by experts and novices: analysis of a complex cognitive skill". *Computers in human behaviour*, 21, 487-508.

Brush, T. & Saye, J. (2001). "The Use of Embedded Scaffolds with Hypermedia-Supported Student-Centered Learning". *Journal of Educational Multimedia and Hypermedia*, 10, 4, 333-356.

Dodge, B., (1995). "WebQuests: A Technique for Internet-Based Learning". *Distance Educator* 1(2), 10-13.

Eisenberg, M. B, & Berkowitz, R.E. (1990). *Information-problem solving: the big six skills approach to library and information skills instruction. Norwood*, NJ: Ablex.

Eisenberg, M. B, & Berkowitz, R.E. (2000). *Teaching Information and Technology Skills: The Big6 in secondary Schools.* Linworth publishers.

Guinee, K., Eagleton, M. & Hall, T., (2003). "Adolescents' Internet search strategies: drawing upon familiar cognitive paradigms when accessing electronic information sources". *Journal of Educational Computing Research* 29 (3), 363-374.

Hakkarainen, K. (2003). "Emergence of progressive-inquiry culture in computer-supported collaborative learning". *Learning Environments Research* 6, 199-220.

Hill, J. R. (1999). "A conceptual framework for understanding information seeking in open ended information systems". *Educational Technology Research and Development*, 47 (1), 5-27.

Hoffman, J., Wu, H., Krajcik, J. & Soloway, E., 2003. "The nature of middle school learners' science content understandings with the use of on-line resources". *Journal of Research in Science Teaching,* 40 (3), 323-346.

Land, S. & Greene, B., (2000). "Project-based learning with the World Wide Web: a qualitative study of resource integration". *Educational Technology Research and Development,* 48 (1), 45-67.

Lazonder, A. W., (2000). "Exploring novice users' training needs in searching information on the WWW". *Journal of computer Assisted Learning,* 16 (4), 326-335.

Lim, B. (2004). "Challenges and Issues in Designing Inquiry on the Web". *British Journal of Educational Technology*, 35 (5), 627-643.

Martinello, M., & Cook, G. (2000). *Interdisciplinary Inquiry in Teaching and Learning*. 2nd Edition, Pearson Education, NJ: Upper Saddle River

Navarro-Prieto, R., Scaife, M. & Rogers, Y., 1999. "Cognitive strategies in web searching". *Proceedings of 5th Conference on Human Factors & Web.* June. Maryland.

Oliver-Hoyo, M., D. Allen, D, & M. Anderson (2004). "Inquiry-guided Instruction". *Journal of College Science Teaching* 33 (6): 20–24.

Pejtersen, A. M. & Fidel, R., (1999). "A framework for work centred evaluation and design: A case study of Information. Retrieval on the Web". *Working paper for Mira workshop.* http://www.dcs.gla.ac.uk/mira/workshops/grenoble/fp.pdf. 3-01-2006

Perkins, D. N., Crismond, D., Simmons, R., & Unger, C., (1995). "Inside understanding". In D. N. Perkins, J. L. Schwartz, M. M. West, & M. S. Wiske (eds.), *Software goes to school: Teaching for understanding with new technologies*, . New York, NY: Oxford University Press, 70-87

Prince, M., & R.M. Felder (2006). "Inductive teaching and learning methods: Definitions, comparisons and research bases". *Journal of Engineering Education* 95 (2), 123–38.

Rosenshine, B. & Meister, C., (1992). "The use of scaffolds for teaching higher-level cognitive strategies". *Educational Leadership,* 49(7), 26-33.

Ryder, R. J. & Graves, M. F., (1997). « Using the internet to enhance student's reading, writing, and information-gathering skills". *Journal of Adolescent & Adult Literacy,* 40(4), 244-254

Scardamalia, M. & Bereiter, C. (1994). "Computer support for knowledge-building communities". *The journal of the learning sciences*, 3, 265-283.

Steel, E.A., Kelsey, K.A., & Morita, J. (2004): "The Truth About Science: A Middle School Curriculum Teaching the Scientific Method and Data Analysis in an Ecology Context", *Environmental and Ecological Statistics*, 11, 21-29.