Also publ. in: Advanced Users: Information Literacy and Customized Services / Oliver Kohl-Frey, Bernd Schmid-Ruhe (Eds.). Konstanz 2008, pp. 53-71

Alexis Smith Macklin, F. Bartow Culp
Purdue University

Reaching Graduate Students: A Community of Practice for Teaching ICT Literacy

Abstract

This study explored the use of a community of practice for teaching information and communication technology (ICT) skills to graduate students. Two questions were posed. The first addressed the ICT skill needs of 15 students enrolled in a research methods course in chemistry education. The second focused on the use of a community of practice to facilitate ICT skill acquisition. Both qualitative and quantitative data were collected and analyzed. Results indicate that ICT instruction was most useful when: 1) students defined/interpreted information needs by recalling prior knowledge and experiences; 2) those interpretations were tested, refined, rejected, or revised for a specific purpose; 3) access to resources and tools (artifacts, symbols, and language) were readily available; and 4) formative feedback supported critical thinking about the information retrieval process. These findings provided important insights into using a community of practice to facilitate and reinforce learning.

Introduction

According to the National Committee of Inquiry into Higher Education (NCIHE), college and university administrators acknowledge ICT literacy as “key skills” for graduates in a knowledge-driven economy (1997). In fact, Purdue University’s strategic plan states that all students will graduate information and computer literate (H. Webb, personal communication, August 2, 2006), but there is no plan of action for accomplishing this task – nor is there a method for assessing students’ skills to see if they acquired them during their academic training. This dilemma is pervasive. Breivik’s

(1998; 2005) research indicated that students are entering higher education, including graduate school, lacking basic ICT skills and, because these skills are not being taught or reinforced in the classroom, they are also entering the workforce with a deficit of critical ICT abilities. As a result, the Computer Science and Techno communications Board (CSTB) and the National Research Council (NRC) issued a report (NRC, 1999) that identified three areas higher education should be addressing to support ICT literacy and better prepare graduates:

- Foundational skills: “the basic principles and ideas of computers, networks, and information” (pp. 2-3).
- Contemporary skills: “the ability to use particular (and contemporary) hardware or software resources to accomplish information processing tasks” (p. 18).
- Intellectual capabilities: skills that “integrate knowledge specific to information technology with problem domains” (p. 20).

Academic librarians attempt to teach skills that address complex information problem solving with library instruction sessions, formerly called bibliographic instruction (Farber, 1999), but at lower levels of skill acquisition. Resource constraints often preclude these sessions from concentrating on knowledge for increasing intellectual capabilities and problem solving skills needed for graduate level research, particularly as they relate to information technologies within specific subject domains. Still, the demand for some type of instruction is evident. According to the Association of Research Libraries (ARL, 2004), requests for library instruction sessions (group presentations) continue to remain high – increasing by 50% since 1991:

> “The typical ARL library offered 768 “teaching” sessions in 2003-04. If we assume that each session was at least an hour long, then the median ARL library offered the equivalent of 21 three-hour credit courses last year. Since a median number of 13,034 people received formal education through library instruction in a typical ARL library, those 768 “teaching” sessions averaged about 17 attendees ”(p. 7).

At both the graduate and undergraduate level library instruction is often designated to one 50-minute session with minimal interaction or follow-up from the instructor of record. Within that period, the expectation is for students to become familiar with various research databases, print resources, advanced search strategies, and evaluation of information to conduct literature reviews for initiating research agendas. Given the nature of ICT literacy skill acquisition, this is unrealistic, but librarians continue to try to meet these demands.

In an effort to address information problem-solving skills heuristic problem-solving models have been developed for teaching Information Literacy skills (Eisenberg & Berkowitz, 1990). These models, which emphasize a hierarchical approach using techniques such as “make a connection between the data and the unknown”, attempt to map to standards of Information Literacy, as defined by the Association of College and Research Libraries (ACRL, 2000):

- Determine the extent of information needed
- Access the needed information effectively and efficiently
- Evaluate information and its sources critically
- Incorporate selected information into one’s knowledge base
- Use information effectively to accomplish a specific purpose

While there is substantial literature over the past four decades on using heuristic models to teach problem-solving skills (Eisenberg & Berkowitz, 1990; McAllister, 1994; Polya, 1957), current researchers question this approach. In particular, Lesh and Harel (2003) argued that these models do not provide an explanation of students’ problem solving processes in individual problem-solving sessions, nor do they help understand the situated development of general reasoning skills necessary for Information Literacy. diSessa (1988) stated that problem-solving activities are more situated, multidimensional, and unstable and require more useful ways to synthesize information, define information goals, and determine solution paths. This interpretation process may include filtering and sorting given information, and testing and revising possible products, especially at the graduate level. Students’ reasoning about the situation is revealed in the process of developing interpretations, explanations, predictions, and descriptions that are related to the problem situation (Lesh & Doerr, 2003).

This approach requires multiple cycles of interpretation beginning with fragmented or confused interpretations of the problem (Kulhthau, 1993), but resulting in more complete, sophisticated solutions (Lesh, Hoover, Hole, Kelly & Post, 2000). Although teaching ICT skills this way is a much more intricate process than the linear stages proposed by the heuristic models, it targets the skills graduate students need for successful information problem solving. For the purpose of this study, the librarians collaborated with the instructor of record to address those skills that would support the students in the development of a research agenda by building on existing knowledge structures, in particular the ability to evaluate and synthesize information.

Lesh (2002) explained that to learn about the nature of students' developing knowledge, it is useful to focus on tasks in which the resulting products demonstrate significant information about the ways of thinking that produced them. This means that students need to be able to communicate – through descriptions, explanations, and constructions – how they interpreted a task or problem-solving situation, and selected information to support their representations (or hypotheses). Through testing, revealing, modifying, and refining their thinking, the collective knowledge of the group changes as students develop models for making sense of their experiences. An important characteristic of these kinds of activities is that students generate meaningful solutions (descriptions, explanations, and constructions) to integrate into their own knowledge bases and to share with others (Wenger, 2000). These products perform the same role of documenting and exposing critical information about problem-solving processes during information retrieval and use.

Rationale

Global industry, international media, and academic institutions are increasingly using the term "ICT literate" to define the key qualities and competencies they are looking for in well-educated people. These include a combination of cognitive proficiencies (the ability to identify and address information needs and problems) and technical proficiencies (the ability to use digital tools, software, and infrastructure that facilitate the creation, storage, manipulation, and transfer of information) (Newell & Simon, 1972). While appropriate application of ICT literacy skills entails recognition of social, educational, ethical, and economic issues, the characteristics of an ICT literate person include the ability to (Katz et al., 2004):

- **Define:** Formulate a research statement to facilitate the search for information
- **Access:** Find and retrieve information from a variety of sources
- **Evaluate:** Judge the usefulness and sufficiency of information for a specific purpose
- **Manage:** Organize information for later retrieval
- **Integrate:** Summarize or otherwise synthesize information from a variety of sources
- **Create:** Generate or adapt online information to express or support a point
- **Communicate:** Adapt information for an audience for delivery via a different medium (e.g., e-mail, presentation software, word documents, and spreadsheets)

In January 2001, the Educational Testing Service (ETS) convened an International ICT Literacy Panel to study the growing importance of existing and emerging information and communication technologies and their relationship to digital age literacy. In recognition that critical ICT literacy skills were not being addressed in higher education, a consortium of experts in ICT literacy assembled to serve as advisors to ETS test developers as they designed an Internet-delivered assessment that measures students' abilities to research, organize, and communicate information using technology. Development of the iSkills TM assessment is a key component of raising the awareness of the importance of ICT literacy as a foundational skill critical for success in higher education and the workplace. For this study, the test was used to benchmark graduate students' proficiency levels and to make decisions about curriculum integration in a research methods course.

Three assumptions about how graduate students acquire ICT skills guided this study: First, knowledge is socially constructed (Bandura, 1977; Vygotsky, 1978; Vygotsky, 1986) and students learn to use information technologies by testing their ideas in real-world situations; Second, real-world problems of interest to the students motivate them to learn and retain ICT skills (Lave & Wenger, 1991); Third, the construction of knowledge is reinforced when students produce something tangible to demonstrate that they have in fact achieved the desired learning outcome (Lesh et al., 2000). For the purpose of this investigation, a community of practice was used to investigate how students construct (and co-construct) ICT knowledge to solve information problems. Jonassen (1999) stated that the model for designing constructivist learning environments focuses on a problem, question, or project.

Problem-based Learning

Problem-based learning (PBL) was used as a means to empower students to conduct research, and apply knowledge and skills to develop a viable solution to a given problem (Savery, 2006). This approach to teaching and learning started at McMaster University in 1969 as the result of curriculum reform for medical schools. It is now recognized as an innovative instructional methodology and is used across disciplines (Duch, Groh & Allen, 2001). The problems are deliberately ill-structured (or open-ended) and are typically based on real-life situations; they are designed for thoughtful and careful analysis to help improve critical thinking skills by applying the learner's own expertise and experience to data collection, analysis, and formulation of a solution (Jonassen, 2000). As such, these problems have a dual emphasis on developing strategies for learning content, and skills, and constructing knowledge (Hmelo-Silver, 2004).

PBL is well suited to helping students become ICT literate because it situates learning in real-world problems. It has a dual emphasis on developing strategies for learning content, and skills, and constructing knowledge (Hmelo-Silver, 2004). For every problem scenario, there is an individual level of interpretation that takes into consideration a student's own experiences, domain knowledge, bias, etc. For teaching ICT literacy, these scenarios are best developed in collaboration with subject-matter experts where ICT skills are imbedded into the content. As Savery and Duffy (1996) noted, the focus of PBL is on students as constructors of their own knowledge. As such, they are placed in situations where they must develop strategies for identifying learning issues and locating, evaluating, and learning from resources relevant to that issue (p. 143). Because these are also the goals of ICT literacy, using the PBL approach seemed to be a meaningful and productive way to teach and reinforcing skill acquisition.

Communities of Practice

The community of practice provided an environment for sharing experiences, and disseminating information for collaboration and problem solving. This approach put students in situations where they were required to construct knowledge by testing and refining their thinking through activities that are meaningful to them. In order for knowledge to be constructed, however, learning must be anchored in experience and concrete understanding. Lave and Wenger (1991) identified four features that are fundamental to this theoretical perspective:

- **Active construction**: Knowledge that is developed by testing, revising, and refining ideas.
- **Situated learning**: Real-world experiences of individuals such as activities or conversations where knowledge is used and extended to solve problems.
- **Community**: A group of people who come together to build a shared practice for learning, problem-solving, and completing tasks.
- **Discourse**: Shared meanings among community members that evolve through dialog, debate, and negotiation.

In this environment, learning occurs when students actively create their own knowledge by trying to make sense out of material that is presented to them. The librarians' role in this study was to facilitate organizing and directing these activities so that students became responsible for their own learning and the learning of others (Palloff & Pratt, 1999). For ICT instruction, this meant encouraging students to think and talk about information problem solving. These dialogs functioned as a way of formulating, testing, and sharing ideas where students raised questions, proposed hypotheses, and extended their knowledge. As with learning any new concept, competence is gained through practice, participation in problem-solving activities, and argument using rhetoric and analytic discourse (Roth, McGinn, Woszczyna & Boutonné, 1999).

In contrast to learning paradigms that focus on the transmission of information, a discourse perspective such as that provided by the community of practice framework implies learning through active participation (McGinn & Roth, 1999). To encourage this type of behavior, activities should be designed to generate significant information about the ways of thinking that produced them. Specifically, the tasks should be authentic in nature and they should focus on the development of constructs (models or conceptual systems) that provide the foundation for deeper and higher-order understandings (Lesh & Lehrer, 2003). For example, as students present ideas about some phenomenon, they make inferences, predictions, and observations based on assumptions from prior knowledge or experiences. When they engage in debate with other students, they learn to justify and explain their reasoning and suggested actions. As they clarify their own understandings, their representations of the problem become more sophisticated (Lesh, Post & Behr, 1985) and their knowledge increases.

As a theoretical framework for this study, the community of practice served as a means to study how shared knowledge about information retrieval and use progresses and how groups learned to collect, organize, and manage data for problem solving. Traditional learning environments do not support this type of investigation because skill development and understanding are assessed on an individual basis, where there is no evidence of how collective knowledge is used to support the learning process. Researchers, however, are currently using communities of practice as a diagnostic tool for understanding knowing and reasoning by examining the varying degrees of participation within authentic learning environments (McGinn & Roth, 1999; Palincsar, Magnusson, Marano, Ford & Brown, 1998). This is known as "situated learning" because knowledge is situated in practice for a significant purpose, where members of the community work to solve authentic problems (Brown, Collins & Druguid, 1989; Lave & Wenger, 1991). Learning, therefore, occurs in the act of solving the problem and in the social arrangements in which the activity is taking place.

Context

Prior to the start of the semester, the librarians collaborated with the instructor of record for the research methods course in chemistry education to integrate critical ICT skills into the curriculum. They developed a virtual space, similar to a portal, for the community of practice where information could be shared. This space included information selected by the instructor, including seminal works in the field; information selected by the librarians, including online tutorials to guide students using specific databases; and information selected by the students, including relevant journal articles and blog entries on topics covered in class. The librarians played an integral part in maintaining this space, and facilitating the dissemination of information. In addition, they provided the students with research help "on demand" by linking to the online reference desk (both chat and email).

Membership in a community of practice required the librarians to establish a physical presence in the course, where they joined the instructor and the students on a weekly basis to address research, learning needs, and other issues related to the course. They also worked closely with the instructor to design problem-solving activities for improving ICT skills by applying the learner's own expertise and experience to data collection, analysis, and formulation of a solution (Jonassen, 2000). These problems were used to stimulate discussions within the virtual community, as part of the course, and for data collection during the think-aloud protocols.

Methodology

Fifteen students enrolled in the required research methods course for chemistry education participated in this study. They were sectioned into three groups of five for participation in the think-aloud protocols and semi-structured interviews. At the beginning of the semester, they all took the *iSkills* ™ assessment, which was delivered via the Internet in a proctored computer lab. Over a 2.5-hour period, they completed a background questionnaire, assessment tasks, and an exit survey. Each interactive task, separated into five-minute and fifteen-minute tasks, used simulated software with the look and feel of typical applications (databases, search engines, spreadsheets, etc.). There were 16 tasks: 12 five-minute single proficiency activities and four fifteen-minute complex problem-solving scenarios. The simpler tasks contributed to the overall reliability of the assessment whereas the more complex tasks focused on the richer aspects of ICT performance (Katz et al., 2004).

The *iSkills* ™ assessment was appropriate for this study because it is the only evaluation tool currently that addresses both cognitive problem solving and critical thinking skills associated with using technology to handle information. As such, scoring algorithms target decision-making, rather than technical competencies. The assessment measures ICT literacy through seven performance areas, which represent important problem-solving and critical thinking aspects of ICT literacy skills (i.e., define, access, manage, integrate, evaluate, create, communicate)

iSkills ™ score reports provided aggregated data on the performance of the class, as a whole, for the purpose of building an ICT curriculum to meet specific needs. Feedback from individual score reports also enabled comparisons between proficiency levels from other groups of students on campus who took the test, including students enrolled in other graduate-level courses, graduating seniors, and entering freshmen. These comments provided valuable insights into the actual performances on each of seven ICT competencies, including defining an information need, accessing appropriate resources, integrating and managing information, and creating and communicating new ideas.

Think-aloud protocols and semi-structured interviews were conducted weekly, by the librarians, to watch as students engaged in discourse that led to increased understandings about information retrieval and problem solving. Actions (i.e., search behaviors) and reactions (i.e., selection of information) were demonstrated successfully most often when the students had opportunities to practice search strategies and see others practice them, and when they were able to discuss what these activities meant in relationship to other situations (i.e., accessing appropriate resources; establishing evaluation criteria).

Below is an example of one of the activities used for the think-aloud protocols in this study. This particular problem scenario, adapted from Moore's (2007) editorial in the *Journal of Chemistry Education*, is representative of the kinds of discussion and research problems addressed in the research methods course:

Siegrist reports that one important change during her career as a teacher was great improvements in instrumentation and technology. Today's high schools often have instruments and information technology that were not available to college students 40 years ago. Such changes in the tools of the trade are also likely for our students during their careers, and change is accelerating. Therefore it is imperative that our students understand chemistry rather than learning by rote things they expect to be on a test.

How can you engage students who could become excellent chemists but learn in different ways?

During these weekly sessions, students engaged in a process of verbalizations to reveal their assumptions, inferences, misconceptions, and problems associated with information retrieval for a given task (Ericsson & Simon, 1993). They worked in a computer lab in groups of four or five and explained each step of the problem-solving process in as much detail as they were able. They were only prompted to "Say more" if they stopped talking. Each session was audio taped and screen captures of their searches were recorded (when possible). Savery and Duffy (1995) explained how this collaborative process works in a problem-based learning environment:

> "The students begin with the problem "cold" – they do not know what the problem will be until it is presented. They discuss the problem, generating hypotheses based on whatever experience or knowledge they have, identifying relevant facts in the case, and identifying learning issues.
>
> After the session, the students all engage in self-directed learning. There are no assigned texts. Rather, the students are totally responsible for gathering the information from the available medical library and computer databases resources.
>
> After self-directed learning, the students meet again. They begin by evaluating resources – what was useful and what was not so useful. They then begin working on the problem with this new level of understanding "(p. 141).

As the students engaged in these activities, substantial data were generated regarding how they were thinking about information retrieval and use. For example, they made inferences, predictions, and observations based on assumptions from prior knowledge or experiences. They also engaged in debate with each other, as they learned to justify and explain their reasoning and suggested actions. All observable behaviors, discussions, and events were documented systematically and coded for examination.

The following coding structure in Table 1 illustrates concepts that emerged during the think-aloud protocols (Strauss & Corbin, 1998):

Categories	Sample concepts
Justify or explain	Jake: "If they can actually see 3-D models then maybe they can learn better. That just goes back to what I was saying before about auditory or visual – people learn in different ways. We need to do more than just lecture."
Recalling prior experience	Karen: "I heard a talk the other day about lectures and how we learn... well, that the average attention span is about 15 minutes." (Moves to seek approval)
Seeking approval/validation	Karen: "So, it's like you (Jake) were saying, if we lecture for 15 minutes, then vary the activity with something more hands on."
Identifying connection between information retrieved and need	Andrew: "The basic premise of lecture is conveying information rather than getting students involved in the process. So, if we're trying to engage the students, it needs to be something they are actively doing." George: "Moving beyond just spoon feeding information to them. Perhaps some kind of discovery in this type of inquiry environment would help? Like instead of starting with a lecture, start with an experiment?"

Table 1:Coded Categories

Results

Evidence gathered from the *iSkills* ™ assessment (M = 574.8) suggested that students were weakest in skills requiring them to define an information need and evaluating and selecting information appropriate for a given need. As a result, think-aloud activities were designed to focus on proficiencies in those areas. Table 2 provides an overview of the aggregate task performance feedback.

Task	Feedback	% of students providing highest scoring response
Clarifying a project	You selected the best initial question to help clarify the project	64%
Choose a research topic	You correctly reported the criteria fulfilled by the research topic selected	9%
Select the most appropriate category for searching	You selected the most appropriate category for searching	24%
Analyze the possible reasons for poor results from a give Internet search	You analyzed the reason for the poor search results correctly	9%
Search a database to obtain information most helpful to a research project	You selected only the most relevant information for your research project	0%
Evaluate the extent to which a specific information source was useful to your research	You correctly justified use of the information selected	9%

Table 2: Aggregate Task Performance Feedback from iSkills TM Assessment

Data from the think-aloud protocols provided thick, rich descriptions of the processes students used in information retrieval for problem solving activities. In addition, the data sources offered tangible evidence in the form of artefacts, models, and tools of how groups and individuals learn to learn within a community of practice. This environment provided a valuable opportunity for investigating and reflecting upon problem-based learning activities and the use of an integrated approach for teaching ICT literacy. As students worked through problems, they needed to discuss what they knew, identify what they did not know, and work though confusion and misunderstandings in the overall concepts being presented.

Three major findings emerged from the data analysis suggesting that the community of practice approach to ICT instruction was successful in helping graduate students understand how to frame an information need, and in modifying search behaviors. These include the use of prior knowledge to make sense of given problems; the use of everyday experiences to make the learning process meaningful; and the use of discourse and debate for task interpretation.

In the first finding, students used their prior experiences to help them identify their place in the group, to give meaning to the problem scenario, and to leverage their existing knowledge on a given topic to gain credibility among other group members. As students shared what they knew – either from their own experiences or from prior knowledge – they achieved legitimacy and place in the group because they provided experiences others may not have had, but to which they could relate. In addition, students questioned each other's experiences and knowledge to justify their own beliefs and to extend their own knowledge bases. This type of feedback fulfills one of the purposes of a community of practice to promote learning via communication and peer mentoring (Ertmer & Russell, 1999; Lave & Wenger, 1991).

The second finding focuses on the use of a situated learning environment to provide context and meaning for the learning process. Lave (1988) and Greeno (1997) referred to this context as participation in a social practice. For example, the comparison can be made between learning to solve problems in mathematics using traditional textbooks vs. using settings that are more reflective of the kinds of mathematics used in everyday experiences (e.g., completing an assignment vs. making change on the street; Cobb & Bowers, 1999; Lesh et al., 2000). Similarly, a situated perspective provided a unique purpose and intention for acquiring and using critical ICT skills. Students contributed to the development of ICT literacy practices by moving beyond finding information to complete a given task (e.g., fact-finding) to finding information to fulfill a need (e.g., finding relevant information sources to help establish a research agenda). This change in behavior suggests that students were becoming more receptive to the rhetoric of the academic community, and more knowledgeable about using appropriate terminologies for developing search strategies.

The third finding describes the use of discourse and debate to test, reveal, modify, and refine problem-solving strategies. Throughout the study, students engaged in discussions to make sense of their experiences, negotiate meaning, and contribute to a collective knowledge base. These dialogs functioned as a way of formulating and sharing ideas where students raised questions, proposed hypotheses, and extended their knowledge. Discourse within a community of practice fosters a culture of discovery and engagement, where both individuals and the group, as a whole, are learning how to learn (O'Neill, 2001). In contrast to learning paradigms that focus on the transmission of information, a discourse perspective implies learning through active participation (McGinn & Roth, 1999). As with learning any new concept, competence was gained through practice and participation in problem-solving activities (Roth et al., 1999).

The Venn diagram in Figure 1 shows how these finding fit into the overall concept of the community of practice. As students recalled and shared experiences, they were better able to identify information needs based on what they knew – collectively and individually – and what they needed to know regarding a given problem or topic (Pea, 1993). Throughout the study, they were engaged in activities where they were required to select resources and develop artifacts to explain their thinking. These artifacts included annotated bibliographies, research journals, and products to disseminate new information. Through continuous discussion and debate, they were able to develop criteria for choosing the most relevant information. Eventually, they learned how to test and refine their thinking about the information goals, selection of resources, and evaluation and use of information to formulate solutions (Rosebery, Warren, & Conant, 1992).

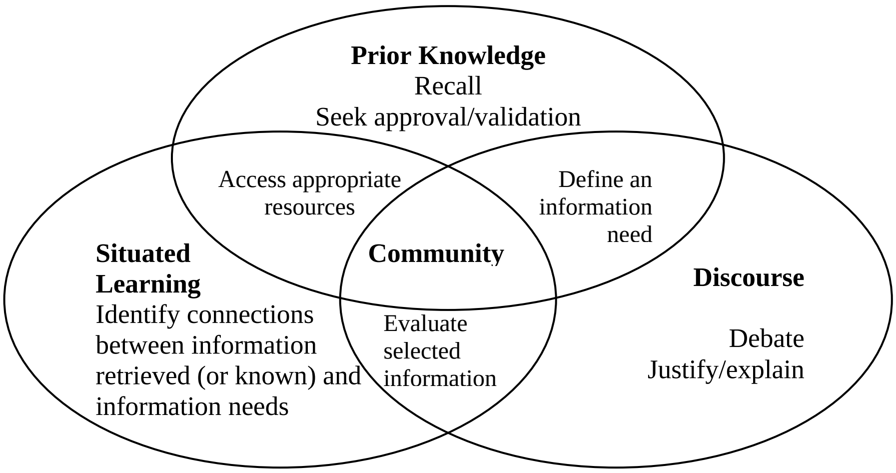

Figure 1. Relationship between research findings and principles of a community of practice.

Conclusion

The findings of this study indicated that when using a community of practice, to teach and reinforce ICT skills, students were able to 1) formulate more sophisticated problem representations than they did on their own by sharing experiences and prior knowledge, 2) create a shared repertoire of these experiences and collective knowledge to build and refine their search strategies, and 3) use discourse to validate their decisions and actions, as well as extend their proficiency levels beyond what they could do on their own to find and select relevant information. This research addresses the pedagogical needs Carey (1998) identified, moving instruction from the current practice of teaching library skills to using an integrated problem-solving approach to teach critical thinking for Information Literacy.

The results of this study showed behavioral changes in the ways in which students found and used information as noted in observations, transcripts of interviews and protocols, and documented in assignments and projects. Despite the fact that the sample size was small, students' collectively demonstrated a shift from weakly defined information goals, to well-articulated research needs, and using a thoughtful efficient approach to selecting keywords and search strategies. Given more time, greater changes may have been possible. The three findings from this study, however, have led to specific suggestions regarding ways to support graduate-level ICT skills including creating learning environments that invite discourse, developing a sense of community through shared experiences, and reinforcing skill development by providing opportunities for testing, refining, and revising ideas.

Finally, there are three assertions, based on practice and the results of this investigation, regarding next steps for those interested in promoting ICT literacy skill using a community of practice approach.

- The traditional 50-minute Information Literacy session is insufficient to meet graduate students' research needs.
- Assessment practices for ICT skills should be conducted so that instruction can be developed and revised as needed.
- ICT literacy education is too demanding for librarians to manage alone. Rather, they should collaborate with subject matter faculty to integrate these competencies into the curriculum, and reinforce skill development through active participation in information problem solving activities.

The third assertion is perhaps the most important. Breivik (2005) indicated that more collaboration is the only way to effectively teach ICT competencies. As experts on the topic, librarians need to be proactive in explaining what ICT literacy is and how it will help improve student-learning outcomes. Using a problem-based learning approach, the results of this study extend the existing research (Eisenberg & Berkowitz, 1990; Kuhlthau, 1993; Webber & Johnston, 2000) by demonstrating an innovative way to incorporate these skills into the curriculum through a community of practice, and by using *iSkills* ™ for establishing valid and reliable benchmarks to address critical learning needs.

References

Association of College and Research Libraries (ACRL). (2000). *Information Literacy Competencies for Higher Education.* Retrieved December 19, 2004, from http://www.ala.org/Content/NavigationMenu/ACRL/Standards_and_Guidelines/Information_Literacy_Competency_Standards_for_Higher_Education.htm

Association of Research Library (ARL). (2004). Statistics. Retrieved August 27, 2004, from http://www.arl.org/stats/arlstat/

Bandura, A. (1977). *Social learning theory*. New York: General Learning Press.

Breivik, P. S. (1998). *Student learning in the information age.* Phoenix, AZ: Oryx Press.

Breivik, P. S. (2005). 21st century learning and Information Literacy. *Change, 37(2),* 20-28.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18(1)*, 32-42.

Carey, J. O. (1998). Library skills, information skills, and Information Literacy: Implication for teaching and learning. *School Library Media Quarterly*. Retrieved May 15, 2006, from http://www.ala.org/ala/aasl/aaslpubsandjournals/slmrb/slmrcontents/volume11998slmqocarey.cfm

diSessa, A.A. (1988). Knowledge in pieces. In G. Forman & P. B. Pufall (Eds.), *Constructivism in the computer age* (pp. 49–70). Hillsdale, NJ: Lawrence Erlbaum.

Duch, B., Groh, S., & Allen, D. (2001). *The power of problem-based learning: A practical "how to" for teaching undergraduate courses in any discipline*. Sterling, VA: Stylus.

Eisenberg, M., & Berkowitz, R. (1990). *Information problem-solving: The Big6 ™ Skills approach to library information skills instruction.* Norwood, NJ: Ablex.

Eisenberg, M. B., Lowe, C. A., & Spitzer, K.L. (2004). *Information Literacy: Essential skills for the Information Age* (2nd ed.). Westport, CT: Libraries Unlimited.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (rev. ed.). Cambridge, MA: MIT Press.

Ertmer, P. A., & Russell, J. D. (1995). Using case studies to enhance instructional design education. *Educational Technology, 35(4)*, 23-31.

Farber, E. (1999). Faculty-librarian cooperation: A personal retrospective. *Reference Services Review*, *27*, 229-234.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher*, *26*(*1*), 5-17.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*, 235–266.

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models* (Vol. 2, pp. 215-239). Mahwah, NJ: Lawrence Erlbaum.

Katz, I. R., Williamson, D. M., Nadelman, H. L, Kirsch, I., Almond, R. G., Cooper, P. L., Readmon, M. L., & Zapata, D. (2004). *Assessing information and communications technology literacy for higher education.* Paper presented at the 30th Annual Conference of the International Association of Educational Assessment (IAEA), Philadelphia, PA. Retrieved November 11, 2005, from www.ets.org/iaea

Kulhthau, C. C. (1993). A principle of uncertainty for information seeking. *Journal of Documentation*, *49*, 339-355.

Lave, J. (1988). *Cognition in practice: Mind, mathematics, and culture in everyday life*. Cambridge: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge University Press.

Lesh, R. (2002). Research design in mathematics education: Focusing on design experiments. In L. English (Ed.), *International handbook of research design in mathematics education* (pp. 27-51). Mahwah, NJ: Lawrence Erlbaum.

Lesh, R., & Doerr, H. (2003). In what ways does a models and modeling perspective move beyond constructivism? In R. Lesh & H. Doerr (Eds.), *Beyond constructivism: A models and modeling perspective on teaching, learning, and problem solving in mathematics education* (pp. 383–403*)*. Hillsdale, NJ: Lawrence Erlbaum.

Lesh, R., & Harel, G. (2003). Problem solving, modeling, and local conceptual development. *Mathematical Thinking & Learning*, *5*, 157-189.

Lesh, R., Hoover, M., Hole, B., Kelly, A., & Post, T. (2000). Principles for developing thought-revealing activities for students and teachers. In E. Kelly & R. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 591-645). Mahwah, NJ: Lawrence Erlbaum.

Lesh, R., Post, T., & Behr, M. (1987). Representations and traditions among representations in mathematics learning and problem solving. In C. Janvier (Ed.), *Problems of representation in teaching and learning mathematics* (pp. 33-40). Hillsdale, NJ: Lawrence Erlbaum.

McAllister, H. C. (1994). *21st century problem solving*. Retrieved February 15, 2000, from http://www.suremath/suremath/home1.html

McGinn, M. K., & Roth, W. H. (1999). Preparing students for competent scientific practice: Implications of recent research in science and technology. *Educational Researcher*, *28*(*3*), 14-24.

Moore, J. W. (2007). Mutual respect provides a strong basis for both teaching and learning. *Journal of Chemical Education*, *84,* 1399.

National Committee of Inquiry into Higher Education (NCIHE). (1997). *A report*. Retrieved November 12, 2005, from http://www.leeds.ac.uk/educol/niche/

National Research Council (NRC). (1999). *Being fluent with information technology.* Committee on information technology literacy. Washington, DC: National Academy Press.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

O'Neill, D. K. (2001). Knowing when you've brought them in: Scientific genre knowledge and communities of practice. *The Journal of the Learning Sciences*, *10*, 223–264.

Palincsar, A. S., Magnusson, S. J., Marano, N., Ford, D., & Brown, N. (1998). Designing a community of practice: Principles and practices of the CiSML community. *Teaching and Teacher Education*, *14*(*1*)*,* 5 –19.

Palloff, R., & Pratt, K. (1999). *Building learning communities in cyberspace: Effective strategies for the online classroom*. San Francisco, CA: Jossey-Bass.

Pea, R. D. (1993). Learning scientific concepts through material and social activities: Conversational analysis meets conceptual change. *Educational Psychologist*, *28*, 265-277.

Polya, G. (1957). *How to solve it* (2nd ed). Princeton, NJ: Princeton University Press.

Purdue University. (2001). *Strategic plan: Goals.* Retrieved September 15, 2004, from http://www.purdue.edu/oop/strategic_plan/

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriate scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences*, *2*, 61-94.

Roth, W-M., McGinn, M. K., Woszczyna, C., & Boutonné, S. (1999). Differential participation during science conversations: The interaction of focal artifacts, social configurations, and physical arrangements. *The Journal of the Learning Sciences*, *8*, 293-347.

Savery, J. (2006). Overview of PBL: Definitions and distinctions. *The Interdisciplinary Journal of Problem-based Learning*, *1*(*1*), 9-22.

Savery, J. R., & Duffy, T. M. (1996). Problem-based Learning: An instructional model and its constructivist framework. In B. G. Wilson, *Constructivist learning environments: Case studies in instructional design* (pp. 135-148). Englewood Cliffs, NJ: Educational Technology.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard Press.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: The MIT Press.

Webber, S., & Johnston, B. (2000). Conceptions of Information Literacy: New perspectives and implications. *Journal of Information Science*, *26*, 381–397.

Wenger, E. (2000). Communities of practice and social learning systems. *Organization*, *7*, 225-246.