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The Development of Pre-Service Science Teachers' Professional Knowledge in utilizing ICT to support Professional Lives

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In the rapidly developing digital world, technology is and will be a force in workplaces, communities, and everyday lives in the 21st century. Information and Communication Technology (ICT) including computer hardware/software, networking and other technologies such as audio, video, and other multimedia tools became learning tools for students in the 21st century. ICT also changed the nature of the teachers' work and the way they relate to other teachers in their professional lives. The researcher designed and implemented a course to enhance 18 pre-service science teachers' professional knowledge, which knowledge of instructional media and technology is one of the important domains. Technology was used as a tool for enhancing the development of professional knowledge in a seminar organizing activity in which students designed instructional movies and participated in online discussion activities. Data from questionnaires, classroom observation, journals, online discussion boards, and pre-service science teachers' artifacts were analyzed by the constant comparative method. The results revealed that most of the pre-service science teachers felt more comfortable using software and hardware, were willing to learn, improve their creativity, participate in group collaboration, and felt free asking questions and reflecting on their ideas on discussion boards. The results show that pre-service science teachers develop their professional knowledge when they are engaged in embedding ICT in subject teaching activities.

Keywords: ICT, Pre-service Science Teacher, Professional Knowledge, Teacher Education

INTRODUCTION

Over several decades, many learning resources such as educational documents and instructional media have been produced in electronic formats. This is causing the learning process to change from paper resources to electronic resources. An essential tool used by humans to acquire knowledge in the 21st century is Information and Communication Technology (ICT) and ICT literacy is critical for today's students (Partnership for 21st century skills, 2007). ICT literacy was broadly defined as a combination of computer skills and knowledge of how to use information in new formats made possible by computers (Sellen, 2002).

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When workplaces, communities, and everyday life require skills for the 21st century, students need to be trained for it. 21st century skills include reading, writing, computing, and how to use essential tools such as computer hardware/software, networking, and other technologies such as audio, video, and multimedia tools (Partnership for 21st century skills, 2007). Teachers are an important aspect of ICT skill acquisition. But teachers cannot prepare students for 21st century context unless they understand, posses, and use those skills themselves (Laferriere et al., 2006).

The domains within teacher professional knowledge as defined in the professional literature include:

- knowledge of educational context,
- general pedagogical knowledge,
- subject matter knowledge, pedagogical content knowledge (Elbaz, 1981; Nazri, 1990; Vonk, 1995; Collinson, 1996; NSTA, 2003; and Leou & Liu, 2004),
- knowledge of instructional media and technology,
- knowledge of educational philosophy, and
- knowledge of research on best practices (Nazri, 1990; NSTA, 2003; and Leou & Liu, 2004).

Knowledge of instructional media and technology has become one of most essential domains in this century.

Teacher professional knowledge is not only related to knowledge and teaching practice, but also other professional roles in and outside the classroom including tutoring students, participating in school activities and projects, interacting with members of the community, and working in professional groups. As ICT changes the environment in which teachers work and the way they relate to other teachers, it has an important impact on the nature of the teachers' profession (Pedro da Ponte, et al., 2002). In the workplace, teachers have been encouraged to use technology in their subject teaching, both at in service and pre-service levels (Mishra and Koehler, 2006; Kay 2006, Galanouli, et al., 2004) including teaching-with-technology, designing software and creating of technologically based tools to support their professional work (Kerr, 1989).

So, now in teacher education, to prepare professional teachers, a web-based system has been suggested as a tool for revitalizing and reforming teacher education courses (Shi, et al., 2004, Barnett, 2006; Ikpeze, 2007; Kay, 2006; Laferriere, et al., 2006; Pedro da Ponte, et al., 2002; and Rodrigues, et al., 2003). Multiple strategies have been used such as web page design (Pedro da Ponte, et al., 2002 and Shi, et al., 2004), digital photography and PowerPoint presentations (Wursta, et al., 2004), technology-based search activities (Bahr, et al., 2004, Shi, et al., 2004, Schrader, et al., 2003), online discussion (Laferriere et al., 2006; Kay, 2006; and Ikpeze, 2007) and movie production (Mishra and Koehler, 2006).

Among these, technology-based search activities, in which teachers use the web to identify resources that support their teaching, helps teachers use technology as a tool in the classroom to improve instruction. Online discussion provides opportunities for teachers to reflect, collaborate, and share ideas with other members in the group. This activity can be used effectively to enhance development of teachers' professional knowledge (Ikpeze, 2007). Producing a video or movie is another strategy which is based on a "learning technology by design" approach (Mishra and Koehler, 2006) and helps learners to become practitioners who construct artifacts, and change from passive learners to learners who take control of their learning (Mishra and Koehler, 2006; Condie and Livingston, 2007).

Recently, there have been many updated software tools that can be used to support these activities through a web-based system. Teachers must simply select the ones that meet their specific content or pedagogical goals (Mishra and Koehler, 2006).

Objective of the study

This study is one part of the development of a course to enhance pre-service science teachers' professional knowledge. This part aimed to determine in what way does the course enhance pre-service science teachers' knowledge of instructional media and technology, and other related domains of professional knowledge during the course?

MATERIALS AND METHODS

Research Design

To answer the question of the study, a qualitative interpretive study was employed as the research design. From this design, the researcher inferred the development of pre-service science teachers' professional knowledge in terms of instructional media and technology use through activities related to designing instructional movies, and online discussion activities in the course.

Research Participants

The participants of this study were a group of eighteen 4th year pre-service science teachers who were enrolled in a 15-week capstone course in the first semester of the 2006 academic year in the Faculty of Education at an institution in Central Thailand.

Research intervention: a capstone course method course

The researcher acted as the course instructor in this study. Two hours a week, for fifteen weeks, the capstone course aimed to enhance pre-service science teachers' professional knowledge by using the seminar process.

There were many course activities used to enhance each domain of professional knowledge. Instructional media and technology was an organizing aspect of the seminar through online discussion and instructional movie production activities.

The seminar required groups of pre-service science teachers to search for information from online and other sources and to be responsible for being a leader for a weekly seminar. Each group, consisting of two to three people, planned, searched, concluded, and presented information in the form of a seminar discussion activity. This activity aimed to enhance pre-service science teachers' abilities in utilizing ICT as a tool to search for information.

The online discussion activity was introduced and was used from the first week of the course. The researcher constructed a seminar website as a main page, through which members were able to link to the online discussion board. The aim of the online discussion board was to provide opportunities for pre-service teachers' reflections, and to act as another learning resource which class members could access any time and from anywhere.

Windows Movie Maker is a basic program provided on the Windows XP operating system. The researcher selected this program because it is user friendly and appropriate for the classroom context. An example of a video case produced by Windows Movie Maker was first introduced in the 9th week for a discussion activity, and a document about the program was distributed to every pre-service science teacher to study both on paper and via electronic formats.

After that, in the 10th week, a volunteer group of students, who were trained in using the Windows Movie Maker program from the researcher, acted as an instructor group. They organized and facilitated the other pre-service science teachers in a movie production activity. A hundred and twenty minute class was divided into two sections: the first 60 minutes made up the instructional part, and the last 60 minutes made up the practical implementation. In the practical part, each group selected a topic of science, practiced movie production, and presented their instructional movies at the end of class.

At the end of fifteen weeks, one of the seminar course requirements was to produce a short segment of instruction using instructional media. Each group of pre-service science teachers selected topics, methods, and designed instructional media based on their selected science topic.

Data Collection and Analysis

To answer the research question, information acquired from classroom observation, questionnaires, online discussion boards, pre-service science teachers' weekly journals and artifacts was collected and analyzed by using the constant comparative method (Bogdan and Biklen, 2003).

A rating scale questionnaire was designed to capture the readiness of pre-service science teachers in each domain of professional knowledge. One part of the questionnaire was aimed to capture knowledge of instructional media and technology. In this section, there were three items about levels of readiness including producing instructional media, selecting instructional media for science teaching, and utilizing ICT. The questionnaires were completed by participants before and after the course. The scale ranged from low to medium, and medium to high levels of readiness.

In addition, the researcher collected data from online discussion boards and pre-service science teachers' weekly journals and artifacts. Data from every source were read and coded. The classifications emerged from incidents that were written, compared and analyzed to generate the core categories. Finally, all findings were compared and conclusions were drawn to answer the research question.

RESULTS

To present the results, the researcher first report what happened in each activity, and summarizes what knowledge of instructional media and technology was enhanced from every activity in the course. The results from questionnaires before and after the course are reported at the end of this section.

Seminar Organizing Activities

There were seven groups of pre-service science teachers that were responsible for each weekly seminar topic. Topics included lesson plans, cooperative learning, inquiry, lectures/discussion/demonstration, student prior knowledge/assessment, instructional media and technology, classroom management, and science process skills. Each group sent their group seminar proposal to the instructor one week before the seminar started, and at the end of the seminar every group wrote reflections on the seminar organizing activity in their weekly journal.

Results from reflections of the group revealed that ICT knowledge and skills were gained from this activity.

Some groups talked about conducting internet searches in their reflection including:

"After we talked about the information that we needed for the seminar, everybody in my group started searching from internet resources and books. We brought the information to discuss and selected reliable sources" (group 1)

"We searched information from a variety of sources; being an instructor makes me read and search more critically for more information from internet resources to get good information from numerous and reliable sources for what we teach" (group 2)

"We started searching for information from a variety of sources 3 weeks before our group started. At that time I just read topics and printed out a bunch of information without going into the details. I learned it did not work….I should be more critical in searching, so I feel like I haven't wasted my time" (group 3)

"Our group spent most of the time planning and searching for information; we read information from the book first and started looking though the internet which has a variety of sources. We have to critically read, group, and select all information that everybody is able to understand" (group 5)

Some members of each group gained skills in operating software/hardware such as making Power Point Presentations:

"I was responsible for making the PowerPoint presentation, so that enriched my skills in using that program" (group 1)

"I'm the one who made PowerPoint our presentation; this made me skillful and familiar with computers" (group 3)

One group was forced to communicate and plan via e-mail and online conference tools due to a school break.

"Because our seminar preparation is during the school break, we were forced to use email and instant messenger to communicate like teleconferences" (group 4)

From the seminar organizing activity, ICT knowledge and skills of pre-service science teachers were enriched including conducting internet searches, operating software/hardware, and e-mailing and online conference.

Online Discussion Activities in the Course

At the beginning, after the online discussion board was introduced to the class, there was only one pre-service science teacher that posted a question about formative assessment, and none of the others joined the discussion. Therefore, the researcher brought the topic that was posted to the next class and reminded the other class members of the importance of reflection and discussion, and the flow of activity started. The participation of pre-service science teachers and the researcher in online discussion activity is presented in Table 1.

Table 1. Participation of Pre-Service Science Teachers and the Researcher in Online Discussion Activity

1	Topics of Seminar	Participation of: Pre-service Science Teachers	Participation of: Researcher
1	Introduction		- introduced activity
2-4	Student teaching Student teaching lesson plans	- discussed about formative assessment. - expressed personal feelings.	- suggested learning resources - encouraged class members' participation. - comforted class member
5-7	nature of science cooperative learning inquiry	- uploaded pictures. - discussed student teaching, lesson plans. - express personal feelings. - reflected on seminar topics.	- encouraged class members - suggested resources - comforted class members
8-10	lectures/discussion/ demonstration student prior knowledge/ assessment instructional media and technology	- uploaded pictures. - made a link to current news.	- encouraged class members
11-12	classroom management science process skills	- discussed instructional media, classroom management. - uploaded pictures. - express personal feelings. - reflected on seminar topics.	- discussed topics - encouraged class members - comforted class members
13-15	Micro teaching	- expressed personal feelings.	- comforted class member

After the first week, more class members joined the online discussion by asking and answering questions, asking for and suggesting learning resources, posting some photos or links about current scientific news, and also reflecting their feelings about weekly seminar activities. Discussed topics included formative assessment in weeks 2-4, student teaching and lesson plans in weeks 5-7, and instructional media in weeks 11-12. At the end of the course, micro teaching took place. During this time, pre-service science teachers only expressed their personal feelings. As seen in Table 1 above, the researcher engaged in the online discussion activity not only as a participant in the discussion, but also as an encourager for class members' participation along the course.

However, there were many class members who rarely or never participated in online discussion. The reasons behind this were represented in their weekly journals. The reasons were based on personal characteristics and student access to computers. Some pre-service science teachers were not computer literate, and some of them didn't have a personal computer at home or stayed in dormitories where computer access was limited.

The Designing Instructional Movies Activity

From classroom observation and weekly journals, the researcher found out that out of 18 pre-service science teachers, only three knew about the Windows Movie Maker Program. One student had never used the program, and two rarely used the program. None of them thought about using this program to produce instructional media for science teaching.

In this activity, the researcher provided 3 computers, which contained pictures and video resources for class members, and also provided a microphone, speakers, and a webcam for each computer. The instructors, who were a volunteer group of pre-service science teachers, divided other class members into 3 groups.

At the beginning of a hundred and twenty minute class period, (60 minutes of instruction and another 60 minutes of practicing) the instructor group introduced the program and demonstrated how to use it. The first step was importing/capturing video files and putting video clips on a timeline. The second step was about adding effects, transitions or tiles, and the last step involved producing/saving a movie file. In each step, an instructor provided chances for class members to practice with the computer and other instruments.

In the practical section, each group started the process of making an instructional movie production by using Windows Movie Maker. There were one or two students serving as assistants from the instructor group. Groups of pre-service science teachers selected a science topic, planned, and practiced producing instructional movies. In the planning process, every member discussed choosing an appropriate scientific topic within the group. After that, some groups started writing scripts, while the others started searching for pictures and videos. At the end of the class, each group presented a movie, and described how to use it in the classroom. Finally, the remaining groups provided feedback to the presentation group. The researcher engaged as a participation observer during the class. Pre-service science teachers spent time on discussing, debating, filming, editing and revising their projects. There were conversations, practices, laughs, and group process in steps of planning, producing, and presenting the movie.

At the end of the course, out of the 7 groups of pre-service science teachers, 3 groups produced instructional media by using computers to achieve a course requirement. Two of them created instructional media videos and the other one produced an online flip album. Those instructional media were on the topics of parts of trees (grade 7), animal life (grade 7), and earth atmosphere (grade 8).

Each artifact, instructional media CD and manual was analyzed and coded according to the domain of the teacher professional knowledge that was enhanced. The results are presented in Table 2.

The first group produced instructional media by using the Windows Movie Maker program for grade 7 students in sub-strand 1: Living Things and Living Processes. Level standards were identified in the instructional CD manual as "Investigate, search for information, discuss and explain structures and functions of various systems in living things (plant, animal, and man), interrelationship of functions and apply knowledge acquired". Correct and appropriate content was presented in the file about structures and functions of plants. They recommended using this file as a supplemental resource that represented real structures of trees. Knowledge of instructional media and technology used in producing the file included filming, searching, importing pictures and video files, operating software/hardware, and producing movies.

The second group produced instructional media by using the Windows Movie Maker program for grade 7 students in sub-strand 2: Life and the Environment. Level standards were identified in the instructional CD manual as "Explore and analyze status of various local ecosystems, explain relationships between components within the eco-system, energy transfer, cycles of substances and change of population size". Correct and appropriate content was presented in the file about relationships of animal life within the eco-system. They recommended using this file as instructional media during the introduction of science a lesson for engaging student interests and inquiring about student prior knowledge. Knowledge of instructional media and

Table 2. Professional knowledge of Pre-Service Science Teachers that was enhanced in producing instructional media videos

Professional knowledge	Program (Science Topics	Windows Movie Maker: TV Program (Trees)	Windows Movie Maker : Music Video (Animal life)	Flip Album: (Earth Atmosphere)
	Grade	7	7	8
knowledge of educational context		Sub-strand1: Living Things and Living Process Level standard Investigate, search for information, discuss and explain structures and functions of various systems in living things (plant, animal, and man), interrelationship of functions and apply knowledge acquired.	Sub-stand 2: Life and the environment Level standard Explore and analyze status of various local ecosystems, explain relationships between components within the eco-system, energy transfer, cycles of substances and change of population size.	Sub-strand 6: Processes that shape the earth Level Standard Search for information, discuss, meteorological phenomena, interpret weather forecasts, explain meteorological changes on living and environment.
subject matter knowledge		- structures and functions of plant	- relationship of animal life within eco-system	- components and stratification of the atmosphere - factors affecting temperature change on earth
general pedagogical knowledge,		- used as a supplemental resource with real structures of trees.	- used as instructional media at introduction of the lesson.	- used as an additional resource with pictures and information about stratification of the atmosphere, ozone layer and greenhouse effect situation.
knowledge of instructional media and technology		- Filming - Searching, importing for pictures and videos files. - operating software/hardware - producing movie	- Searching, importing for pictures, videos and audio files. - operating software/hardware - producing movie	- Searching, importing for pictures files. - operating software/hardware - conducting internet searches

technology used in producing the file including searching, importing pictures, videos and audio files, operating software/hardware and producing movies, and conducting internet searches.

The last group produced instructional media by using the Flip Album program for grade 8 students in Sub-strand 6: Processes that Shape the Earth. Level standards were identified in the instructional CD manual as "Search for information, discuss, meteorological phenomena, interpret weather forecast, explain meteorological changes on living and environment." Correct and appropriate content was presented in the album about components and stratification of the atmosphere, and followed with factors affecting temperature change on earth. They recommended using this file as an additional resource that provided pictures and information about stratification of the atmosphere, ozone layer, and greenhouse effect situation. Knowledge of instructional media and technology used in producing the file included searching, importing pictures and files, operating software/hardware, producing movies, and conducting internet searches.

The Development of Knowledge of Instructional Media and Technology of Pre-Service Science Teachers

The results from activities including seminar presentations, the online discussion board, and the movie production practice were coded, compared, and generated into categories of knowledge of instructional media and technology that were enhanced during the course. The categories are presented in Table 3.

Table 3. Knowledge of instructional media and technology that was enhanced in a capstone course

Knowledge of Instructional Media and Technology	Activities used in course		
	Seminar organizing	Online discussion board	Windows Movie Maker
files formats		/	/
uploading and downloading		/	
operating software/hardware	/	/	/
create hyperlinks		/	
conducting internet searches	/	/	/
produce movie			/
Emailing and teleconferences	/		

/ represents an existence of knowledge of instructional media and technology in each activity.

As seen in Table 3, pre-service science teachers' knowledge of instructional media and technology was enhanced during the course in the areas of files formats, uploading and downloading files, operating software and hardware, create hyperlinks, conducting internet searches, the process of movie production and emailing and teleconferences.

The following quotes represent examples of pre-service science teachers' reflections in weekly journals that were coded in the category called file formats:

"There are many formats of pictures files, these can be .jpg, .gif. If we want animated pictures, we should search for pictures with a .gif"

"The movie files that I know are those that have .wmv, .mov, .mpeg"

In the category of operating software/hardware, pre-service science teachers expressed that

"Now, I know how to use Windows Movie Maker program in producing a movie."

"I know how to use webcam to capture still pictures and movies."

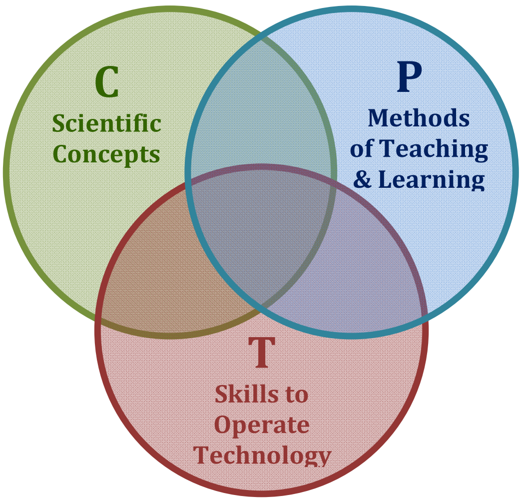

Figure 1. An Integration of Teachers' Professional Knowledge including Scientific, Pedagogical, and Technological Knowledge in the Process of Instructional Movie Production (*Adapted from Mishra and Koehler, 2006*)

"I am getting familiar with using the computer and some programs that I had never used before."

In the online discussion board activity, there were many class members uploading pictures and downloading files from online learning resources. Some of them also made hyperlinks to share knowledge with friends.

Moreover, pre-service science teachers' artifacts showed an integration of their knowledge which included scientific, pedagogical, and technological knowledge in the process of instructional movie production.

The integration of knowledge is presented in Figure 1 using a model of Pedagogical Technological Content Knowledge (TPCK) that was proposed by Mishra and Koehler (2006). Content knowledge is coded as C, pedagogical knowledge as a P and technology as a T.

In designing instructional media videos, pre-service science teachers integrated knowledge of science in specific content areas (content knowledge: CK), pedagogical knowledge (pedagogical knowledge: PK) or methods of teaching and learning into the idea of knowing what teaching approaches fit the content (pedagogical content knowledge: PCK).

When pre-service science teachers had basic knowledge and skills in using technology (TK) for producing instructional movies such as operating software and hardware, searching and importing pictures or video files and filming, they selected an appropriate scientific concept that can be changed by the technology. This referred to an idea of technological content knowledge (TCK).

Pre-service science teachers presented technological pedagogical knowledge (TPK) in applying pedagogical strategies for use of technology. The interweaving of all domains of knowledge including content, pedagogy, and technology was presented in the movie production activity including: using appropriate technology to produce instructional movies as a supplemental resource or as an additional resource to present specific science concepts.

Table 4. The readiness in knowledge of instructional media and technology of pre-service science teachers before and after participating in a capstone course

Item	Knowledge of instructional media and technology		The level of readiness (%)		
			Low	Medium	High
1.	producing instructional media	Before	22.22	72.22	5.56
		After	0	77.78	22.22
2.	selecting instructional media for science teaching	Before	0	83.33	16.67
		After	0	77.78	22.22
3.	utilizing ICT	Before	11.10	83.34	5.56
		After	0	50.00	50.00

Upper row of each item presented percent of readiness before participating in a capstone course.
Lower row of each item presented percent of readiness after participating in a capstone course.

In addition, there were some important characteristics that were enhanced by these activities, such as feeling more comfortable using software and hardware, feeling free in asking and reflecting on ideas, using creativity and artistic abilities, working in collaboration, being willing to learn, and an eager desire to stay up-to-date. Some pre-service science teachers expressed their opinions on benefits and limitations of online discussion boards, and the Windows Movie Maker Program. The online discussion board's beneficial characteristics included being able to access the dialogue at any time and from anywhere. Limitations of this tool included: topics weren't instantly responded to after being posted and computers were not available to everyone. The Windows Movie Maker Program's beneficial characteristics were user friendliness, and accessibility with the Windows XP program already installed on computers. Limitations presented by the group included: the fact that the program does not support a variety of video file formats, and also a limitation of available tools such as computers, webcams and microphones.

Questionnaires: The Readiness of Pre-Service Science Teachers to use Knowledge of Instructional Media and Technology

Results from the questionnaire (Table 4) showed the percentages of responses given by pre-service science teachers about the readiness in knowledge of instructional media and technology before and after participating in a capstone course.

Table 4 shows responses from pre-service science teachers before and after the course. The general trend is toward increased readiness in each area. There are increasing percentages of high level of readiness in all three categories. These changes show that pre-service science teachers felt more ready in their knowledge of instructional media and technology including producing instructional media, selecting instructional media for science teaching, and utilizing ICT after participating in a capstone course.

DISCUSSION

Through the seminar activity, pre-service science teachers utilized their knowledge of instructional media and technology including conducting internet searches, operating software/hardware, and emailing and online conferencing. Their reflections revealed that engaging in technology-based search and presentation activities helped them develop skills related to searching the internet, and utilizing PowerPoint presentations. These are thought to be basic technology skills teachers can use to help support their careers (Dawson, 2008). This finding is comparable to findings of Bahr, et al. (2004), who found that implementing long-term technology in teacher education provided helpful insight into preparing teachers to use technology in the classroom to support instruction (Bahr, et al., 2004).

In the beginning of the online discussion activities, conversations between participants were not flowing well. The researcher, who engaged as a course instructor, encouraged members' participation by reminding them of their course responsibilities. This was based on suggestions from Mishra and Koehler (2006) and Ikpeze (2007). Mishra and Koehler (2006) recommended that the main role of the instructor was facilitating discussion and being a problem solving expert. To accomplish this, the instructor should read postings, synthesize the discussion and provide responses to the class members (Ikpeze, 2007). As the researcher in this study used techniques of this type, online discussion among student improved. These results support the use this recommendation.

The results also showed that although the instructor's role is important, individual student personal characteristics and computer availability can also greatly affect discussion activity outcome. When a topic or a question was posted with no one responding, it was determined that this can be a cause of non-flowing activity. Ikpeze (2007) said interaction stimulates more interaction. That is, discussions that begin to flow sometimes take on a life of their own and will be sustained as members keep responding to one another. In addition, a finding similar to that described by Parkinson (1998) was evident in this study as a significant number of pre-service science teachers did not use ICT in teaching because of their personal feelings and insufficient machines.

Results showed several important characteristics of pre-service science teachers that were enhanced in this activity. These included feeling more comfortable using software and hardware, feeling free in asking and answering questions, and being comfortable in critical reflection. The comfort level in using computers of pre-service science teachers was similar to the findings of Pedro da Ponte, et al. (2002)'s study on mathematic teachers. He was concerned with an anxiety regarding technology as a significant issue for pre-service mathematic teachers' education. He found the pre-service mathematic teachers gained confidence in using computers when participating in the production of web pages designs.

The freedom in asking and answering questions, and critical reflections were associated with issues of student empowerment and active learning proposed by Ikpeze (2007). He said when teachers participated in online discussion, they were able to reflect and exchange ideas among themselves. This was an important method to help them change from being passive to active learners (Ikpeze, 2007).

One main advantage of the online discussion board proposed for pre-service science teachers in the course was opportunity to choose when and where to join an online discussion. This was in line with Rae and Kay Livingston's (2007) suggestions. Their results suggested that e-learning opportunities allowed the students to take control of their own learning. They were able to choose what, when, and where to learn (Rae and Kay Livingston, 2007).

In this study it was found that when pre-service science teachers participate in educational technology activities, they developed not only their professional knowledge of instructional media and technology, but also they learned to integrate other domains of professional knowledge such as scientific and pedagogical knowledge. Their learning process and artifacts showed that they learned how to use technological tools in their subject teaching. This result was aligned with the findings of Mishra and Koehler (2006) and Rodrigues et al. (2003). Mishra and Koehler's (2006) determined that teachers develop knowledge of content, pedagogy, and technology together when they participated in authentic design-based activities. Moreover, using ICT as a tool for science teaching also encouraged teachers' pedagogical content knowledge (Rodrigues et al., 2003). While participating in designing technology based activities, teachers not only learned technology, but how to think deeply about and apply their professional knowledge.

The development of pre-service science teachers' professional knowledge in utilizing ICT to support their professional lives emerged during pre-service science teachers' participation in the course. The teachers' readiness to use knowledge of instructional media and technology was presented in a table which showed that pre-service science teachers were more confident in using technology supported science teaching after the course. These outcomes were comparable with Galanouli, et al. (2004) and Wursta (2004)'s findings, who discovered that utilizing digital photography for modeling best practices (Wursta, 2004), and participated pre-service science teachers in ICT training program (Galanouli, et al., 2004) increased student teachers' pride and confidence in using computers (Galanouli, et al., 2004 and Wursta, 2004).

CONCLUSION

From the results, it can be concluded that this course enhanced pre-service science teachers' professional knowledge in the domain of knowledge of instructional media and technology including the areas of files formats, uploading and downloading files, operating software and hardware, create hyperlinks, conducting internet searches, the process of movie production and emailing and teleconferences. Moreover, pre-service science teachers presented an integration of other related domains of the professional knowledge such as content and pedagogical knowledge with the knowledge of instructional media and technology in the designing of movie activities. The course helped pre-service science teachers develop helpful characteristics and confidence in utilizing technology to support their teaching profession.

Implications and recommendations

There following are recommendations from the study:

1. Teacher education faculty should consider integrating knowledge of instructional media and technology into teacher education courses to prepare pre-service science teachers. They should provide practical experiences for them to integrate this domain with other domains of teacher knowledge into the area of their teaching.

2. To use online discussion as a tool, an instructor should be concerned about the flow of discussion. Every participant should be informed about the importance of responding or providing feedback to every posted question. Moreover, the instructor should consistently visit the online discussion board; provide feedback to ideas, questions or feelings; and also encourage class member participation.

3. To embed ICT in teacher education, a course designer or an instructor should be concerned about the technology available in the classroom context. Computers and other accessories should be provided both in and outside the course to facilitate student teachers' learning and to allow students to practice their skills with this equipment.

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Adoption of ICT in Science Education: a Case Study of Communication Channels in A Teachers' Professional Development Project

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This paper analyses the use of various communication channels in science teachers' professional development project aiming to develop versatile uses for ICT (Information and Communication Technologies) in science teaching. A teacher network was created specifically for this project, and the researchers facilitated three forms of communication concentrating on the topic of ICT in science teaching. The three forms of communication were face-to-face interaction, mediated interaction, and mediated quasi-interaction. Based on case study data and participating teachers' self evaluation, during the course of the project, the use of ICT in science teaching increased. As predicted, face-to-face communication appeared to be felt more effective than mediated interaction or mediated quasi-interaction. However, informal discussions in small groups turned out to be more important than expected. The results suggest that the design of future professional-development projects should make room for more informal communication.

Keywords: Case Study, Communication Channels, ICT, Professional Development

INTRODUCTION

For longer than a decade, one of the key challenges to the professional development of teachers has been to help the integration of ICT into education. Rationales for an increase in ICT use are based on the assumption that the future will be dominated by knowledge-intensive professions, and employees need, therefore, sophisticated information processing skills and versatile ICT tools. Therefore, ICT in teaching is considered important in the facilitation of equal opportunities for citizens to study and develop their own knowledge to ensure the success and welfare of the nation (Schie, 1997; Moursund & Bielefeldt, 1999; OECD, 2004; UNESCO, 2008). However, the implementation of ICT innovations into school practice is difficult. Thus, it is important to initiate research and development in this field in order to discover what contributes to successful adoption of these innovations.

Research literature has shown promising results on benefits of ICT use in education: it supports student collaboration and knowledge building. Further, in the context of science education, it offers possibilities for interaction with the nature; tools for real-time data logging. However, several problem issues have been identified which explain why ICT is not used in teaching in such extent as it could be appropriate according the potentials reported in the literature. Teachers feel a lack of up-to-date computer equipment and software. One interpretation could be that computers tend to be located in computer labs, not in ordinary classrooms or science labs (Newton, 2000; Hakkarainen et al., 2000). The second interpretation could be that teachers have

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had insufficient time to learn about the use of ICT and its applications in science classrooms (see e.g., Russell & Bradley, 1997); consequently, they have no confidence in ICT use. The third interpretation is teachers' 'technophobic' attitudes about ICT in science teaching (Demetriadis et al., 2003). Research suggests that in any topic, including the benefits of ICT in education, it has been difficult to change teachers' beliefs about teaching and learning (Tobin et al., 1994, 64; Willis, 1997). Teachers' beliefs have remained stable, and their resistance to change is one of the main explanations behind the diminutive adoption of ICT in education (Haney, Czerniak & Lumpe, 1996). Knezek and Christensen (2002) found evidence that teachers' beliefs regarding the usefulness of ICT in education appear to be surprisingly consistent across nations and cultures.

For these reasons, many countries have launched programmes to promote the use of ICT in education. New educational policy statements, renewal of curricula, professional development projects, and the production of new pedagogical study materials have been some of the ways to promote the adoption of a new pedagogical innovation, such as the use of ICT in education (Fullan, 1991, 37; Lazarowitz & Tamir, 1994, 121; OECD, 2004). However, it seems that the programmes rarely feature sufficient guidance and in-service training. A shortage of facilitators or trainers and a general lack of ability of educational organisations to provide effective training and facilitation for teacher collaboration are factors interfering with programme success (Moursund & Bielefeldt, 1999).

Even if teachers are doubtful about the use of ICT in education and about their own ICT competence, strategies and in-service training have built on computer-mediated communication between teachers. For example, in Finland, two-thirds of teachers considered their pedagogical and technical ICT skills inadequate in 1999, but the form of in-service training suggested in the Finnish national ICT strategy was to establish virtual schools or computer-supported professional development networks (SETRIS, 2000; see more Niemi, 2003).

The paper focuses on communication in a professional development (PD) project. Several channels were constructed within the project. Thompson (1994, 35–37) distinguished communication channels (media) on the basis of the nature of the interaction. Face-to-face interaction requires that participants share a common spatio-temporal reference system (they are in the same place at the same time) and interaction is dialogical (two-way information flow). Typically, mediated interaction involves the use of a technical medium (phone, e-mail and/or a newsgroup program over the Internet). In this kind of interaction, participants cannot use expressions 'here', 'now', 'this', 'that', etc. unequivocally. Participants must add contextual information to their messages. The third of Thompson's categories is mediated quasi-interaction, typically mass communication (www-pages, newspapers, television). Mediated quasi-interaction has one-way flow of information; and there is a clear distinction between the producer and a receiver of information, even if some kind of consumer feedback may be possible.

Adoption of ICT in science education through communication channels

Following Voogt and van den Akker (2002), we introduced several educational information and communication technologies for the teachers in our PD project: 1) Simulations and modelling systems (compare with professional CAD software); 2) Multimedia; 3) Microcomputer-based laboratory; 4) Basic tools (e.g., word processors, spreadsheets, graphic software); 5) Communication applications (e.g., e-mail, videoconferences, newsgroups, course management systems – compare intranet solutions to share documents) and 6) databases. They emphasise that in the early years of computers, educational applications were mainly drill and practice programs designed for specific and limited purposes. Nowadays, it seems that software in schools does not differ essentially from software used professionally. In particular, tool applications, databases, multimedia, and social media application (web 2.0) are mostly the same for both schools and professionals

The innovation discussed in this research is a versatile use of ICT in science education. The very important feature of the innovation is that teachers themselves, in communication with researchers (writers of this paper) and other teachers, designed the final version of the innovation. The use of ICT with pupils in a classroom forms a unique application of the learning environment that can be seen as an innovation. This kind of use requires flexibility, both from the technical (ICT) and the pedagogical (teaching methods) aspects of the innovation.

Diffusion as defined in this project, is a process by which the versatile use of ICT in science education (innovation), is communicated through face-to-face interaction, mediated interaction, and mediated quasi-interaction (communication channels) organised over a three year period (time) among the teachers participating in our PD project (social system) (Rogers, 1995, 35; Thompson, 1994, 34–37). Based on the general model of Rogers (1995, 10-11), the diffusion and adoption of an innovation are similar to different kinds of innovations and social systems. A common characteristic is that these processes can be charted on a S-shaped curve. Individuals in different phases of adoption process can be called: novice, advanced beginner, competent, proficient, and expert (Eraut, 1994, 124).

Rogers (1995, 11-35) has differentiated the adoption process from the diffusion process and defined the adoption process as an individual's mental process through which he or she passes from first hearing about an innovation to final adoption (or rejection). He emphasised the importance of an interpersonal diffusion network that influences an individual's adoption process (Rogers, 1995, 281-334). The adoption process can be divided into several stages: awareness, interest, evaluation, trial, and adoption. Individuals who are members of the society adopting the innovation can be categorised in adopter categories such as innovators, early adopters, early majority, late majority, and laggards.

Rogers (1995, 5-6) emphasised that communication, a process in which participants create and share information with one another in order to reach a mutual understanding, was essential to the diffusion of innovations. Messages of this kind should be about new ideas, in our case about new uses for ICT in science education.

Research questions

In this research, we followed the teachers participating for three years in the professional development project called the Finnish Virtual School for Science Education. During the project, there were opportunities to share experiences about the use of ICT in education through several communication channels. To explore the way innovations began to be used (in this case, ICT in science education), we asked the following research questions:

How participating teachers' ICT use in science education changed?

Which structure of communication was felt significant in a teacher PD project?

The research method and results

In order to understand how ICT could be integrated into science education (an adoption process), and observe communication about it, we followed Yin's (1994) suggestions to collect case study evidence from multiple sources (data triangulation). Yin (1994, 79) categorised six sources of evidence for case studies: documentation, archival records, interviews, direct observations, participant observations, and physical artefacts. Table 1 describes the data collected during the three years of our PD project activities.

In order to answer the research question concerning the change of teachers' ICT use in science education, teachers were asked to self-evaluate their ICT use in the beginning and in the end of the PD project. During the project, the researchers noted preliminary interpretations about the activities under observation. In order to answer the research question concerning efficient communication channels, the case study data (Table 1) were analysed to describe the key issues and interpretations of the project.

The analysis of the case-study data was conducted in the following way: The first author carefully read the data and selected relevant sections to identify and to obtain information about the communication channels and which of them were efficient from the point of view of how the teachers adopted the use of ICT in science education. The analysis focused on teacher interviews, open answers from teacher surveys, evaluation and planning memoranda, and field notes. During the reading the categorisation of communication channels got its shape. This approach can be called deductive content analysis. Our analysis was based on Thompson's (1994) communication categories. Extracts of text dealing with the use of ICT in science education were read as a whole and different ways teachers utilised or talked about communication channels were used to interpret the felt significance of each communication channel.

The case of Finnish Virtual School for Science Education

This section describes the proceeding of the professional development project based on case study data. During an informal meeting in a previous project, two teachers and one of the authors of this paper made the first moves towards establishing the Finnish Virtual School for Science Education (FVSSE). The group developed the initial goal: to improve learning and teaching in science through the effective use of ICT. The authors presented their plans to the experts working in the Economic Information Office (of Finnish industry) EIO, who saw that the planned Virtual School fitted well within their school collaboration programme. Three municipalities came to be part of the virtual school at the suggestion of the EIO, and two teacher training schools joined when one of the authors asked them to participate (Table 2).

There were large differences in the professional backgrounds of the participating teachers, even if they were all teachers of chemistry and/or physics (and a majority also taught mathematics). There were textbook authors, active participants in the activities of the teachers' pedagogic association, one of them held a PhD in education, another had a broad (Master's) degree covering mathematics, chemistry, physics, and education, a few were members of the Finnish National Curriculum Renewal Committee, and one teacher co-ordinated his own ICT development project financed by the European Structural Fund. There were freshly graduated teachers, retiring teachers, and "ordinary"

Table 1. Case study data collected over the three years of the FVSSE

Type of the evidence	*Description*
Documentation	
E-mail distribution list. Altogether over 230 messages were sent.	Includes mainly information from researchers to participants: about applications, surveys, agendas, and seminars.
Newsgroup postings	During the distance sequences, a simple newsgroup was used to provide a possibility to report and comment on teaching experiments. There were, for example, about 50 postings during the second year, 25 on the experience of using ICT in co-operative learning.
Evaluation and planning memoranda (13)	A researcher wrote a memorandum and evaluation of each seminar and the previous distance sequence, as well as another on planning for the next seminar and distance sequence. A data projector was used for presentation.
Newspaper clippings (5) and journal articles (4)	These documents presented the project to local areas and distributed the newly-developed teaching methods to other teachers.
The project applications	Produced collaboratively in the launching seminar. Researchers made the first draft and participating teachers added aspects that they saw important. The applications were finalised collaboratively in the first seminar.
Seminar agendas (13)	The teachers who hosted the seminar planned the agenda, taking into account the evaluation of the previous seminar.
Annual reports	The researchers wrote an overview of the project and every participating school wrote a description of their developing efforts. Altogether, three annual reports (of 30 – 50 pages) were written.
Archival records	
Budgets	The FVSSE was a municipalities' project. The researchers helped teachers to draw up budgets for each budget year.
Participant records	Contains information about participation in the seminars. The average number of participants was 23 per seminar (including researchers).
Pupil surveys (2)	A web questionnaire asked school pupils how they saw the use of ICT in science education, how easily available computers were, and how they saw their own ICT competence. Conducted at the beginning and at the end of the project.
Teacher surveys (3)	Annual surveys on the use of ICT and project success, including questions about specific teaching methods.
Interviews	
Group interviews (10)	In the spring of 2002, teachers from participating schools were interviewed. One interview was conducted per school. Altogether, 19 of 24 active teachers were interviewed. They were asked to evaluate the project, their own action in the project, and the outcomes of the project.
Open-ended questionnaires (3)	Teacher surveys included several open-ended questions. Teachers were asked to write evaluations similar to those of the interviews. We used three surveys and two teaching-method questionnaires.
Observations	
Participant observation field notes	Researchers wrote field notes during the seminars about working in the seminar and teachers' descriptions of teaching experiments.
Physical artefacts	
Developed teaching methods	Descriptions of the newly-developed teaching methods were published in the web.
Introduction slides	A researcher or a participating teacher started a discussion on a topic. These slides were available on the Internet.
Teachers' written reports	The final reports of the teaching experiments were available on the Internet.

chemistry and physics teachers. Common for all was that they had interest in the clarification of constraints and opportunities for the use of ICT in science education and the improvement of teaching. All of them joined the project voluntarily. Some participating teachers and researchers had experience on many professional development projects, e.g., already in the eighties on the somewhat similar FINISTE project that was a national sub-project of the UN-initiated INISTE network (Kuitunen, 1996).

Appendix 1 describes the seminars' key issues and their interpretation based on content analysis of case study data (Miles & Huberman, 1994; Yin, 1994; Patton, 2002). In the launching seminar, sponsored by the EIO, participant teachers joined the effort to finalise the project plan. In the project plan, the goals of the FVSSE were: (i) to develop new approaches for science education where ICT can be used in a versatile manner within several teaching methods, (ii) to help science teachers to adopt and develop pedagogical models for utilising ICT in science education (e.g., distance learning), and (iii) to foster collaboration between schools and universities and other institutions in the provision of professional development opportunities for teachers.

Twenty-eight teachers, four researchers, and two invited experts participated in the launch seminar. Nineteen were upper secondary school teachers and nine lower secondary school teachers. Only six were under 40 years old; thus, the level of teaching experience was high. As for their main teaching subjects, seven taught chemistry, seven mathematics, and fourteen physics. At the beginning of the project, there were twelve female participants.

In the first seminar (Appendix 1), participants prepared an application for additional funding to enable researcher participation in all seminars as trainers and facilitators, e.g., helping the teachers to be aware of the innovation. The plan was finalised after the first data collection period in September 2000, where the aim was to clarify the teachers' current use of ICT (Table 3). This can be seen as the first step of the decision process that can lead to either the adoption or rejection of an innovation (Rogers, 1995). Teachers gained knowledge about the ICT use in science education.

In the beginning, the project had features of in-service training. Teachers arrived at the seminar and researchers (as trainers) commissioned tasks to be done at their schools before the next seminar. The goal was to help teachers become aware of the advantages of the innovation through introductory lectures. The researchers tried to influence the teachers' attitudes towards the innovation (Rogers, 1995, 20; Rogers, 2001, 7541). Researchers focused on three viewpoints:

Table 2. The municipalities participating in the FVSSE

Municipality	*Description*
Kiuruvesi	Rgural area in eastern Finland, small indursty.
Oulu	Urban area in northern Finland, high-technology industry.
Helsinki – Vantaa	Capital area in southern Finland, one million inhabitants.
Kauhajoki	Western Finland, rural area, small industry.
Eurajoki	Rural area in Western Finland, a site of a nuclear power plant.

Table 3. Using ICT in different ways for teaching science. Distributions are compared with χ^2 analysis.

Computer application category [e]	*Autumn2000* *n = 25* *Median* [a]	*Spring 2003* *n = 22* *Median* [a]	χ^2 [b) c) d)]
(1) Simulations and modelling systems			
Java applets and other simulations	1	2	5.1*
(2) Multimedia			
e.g., Radiation multimedia	2	2	8.6**
(3) Microcomputer based laboratory	1	2	4.6*
(4) Basic tools			
Word processing	2	3	13.3***
Spreadsheets	2	3	8.1**
(5) Communication applications			
E-mail: teacher – student	2	3	5.9*
Newsgroups and learning management systems	1	2	9.4**
Teachers' web publishing	1	2	13.5***
(6) Databases			
Pupils search information on the Internet	2	3	13.2***

a) 1 never; 2 seldom (1 – 3 times a month or 1 – 10 times a term); 3 occasionally (1 – 2 times a week or 11 – 30 times a term); often (3 – 6 times a week or 31 – 100 times a term); 5 daily (several times a day or over 100 times a term).

b) The groups were combined in the $\chi 2$ analysis to get no zero frequencies and 20% of the frequencies over 5.

c) Situations autumn 2000 and spring 2003 are compared

d) * $p < 0,05$, ** $p < 0,01$, *** $p < 0,001$

properties of innovation that enhance learning, compatibility of the innovation for the present learning concept of the participating teachers, and external pressure to increase ICT use in education.

The first area of development, decided by teachers according to their interests, was learning by reading and writing activities. One of the "sub-" innovations was to use the Internet as a source of information. The challenge was to design assignments for school pupils and students that prevented use of the copy-and-paste method. Teachers were engaged in the development of the innovation from the very beginning of the project. One crucial reason for the chosen development area was that computers in the schools were by that time almost exclusively in computer labs, not in science labs. Thus, learning by reading and writing activities was supposed to be easy to start with (cf. Rogers, 2001, 7542).

Teachers from the city of Oulu arranged the logistics for the second seminar (Appendix 1). These teachers chose the teaching experiments and designed the tasks to be done before the next seminar by themselves. The objective of the introductory lectures was to show the advantages and adaptability of the innovation so that participating teachers could evaluate it (cf. Rogers, 2001, 7541–7542; Rogers, 1995, 11–35). The researcher who introduced the innovation, focused on the values, past experiences and needs of teachers to show that the use of ICT in education is consistent with participating teachers' views of learning. Teachers had the skills to use search engines and word processors, but they needed fresh ideas (such as how to use poems, booklets, databases of local newspapers and so on) for versatile computer use in teaching. The researchers challenged teachers to reflect and study what kinds of practices they already used in their classrooms, what they already knew about ICT in science education, what else they wanted to know, and how they might apply new approaches developed during the project in their everyday teaching.

From the beginning of the project, at the end of each seminar there were collaborative evaluation and planning sessions (see Table 1). Researchers acted as facilitators taking notes of participants' comments and ideas. Various approaches (e.g., the principles of creative problem solving) were followed to promote a positive, non-judgemental atmosphere. For example, there was room for free ideation and all ideas, even absurd or impractical ones, got positive feedback (Parker, 1991; Higgins, 1994, 119). In this way, the lectures and workshops organised during seminars were based on teachers' reflections and suggestions.

After one academic year, teachers started to focus on their own main interest areas. These areas included inter-school learning management system projects, MBL, using simulations or videos, and progressive inquiry. The role of the researchers was to help teachers arrange teaching experiments and make trial runs of the innovation (cf. Rogers, 1995, 11–35). For example, teachers used the course management system of the university. They could consult a researcher on such details as how to design a web course. Researchers provided both technical and pedagogical advice. The objective was to make the innovation less complex and to help the teacher try course management systems (cf. Rogers, 2001, 7542).

In the above paragraphs, the progression of FVSSE was described. Table 3 shows the self-evaluations of participating teachers' use of ICT at the beginning and at the end of the project. This table indicates that there was a positive general development with statistically significant changes in all categories.

Channels of communication structured in the professional development project

The virtual school of science education FVSSE was launched as a professional development project for teachers. The main idea was to create a collaborative community reaching a critical mass to help teachers share and develop their ideas about the use of ICT in science education. According to Rogers (2001, 7540): "Research on the diffusion process shows the essentially social nature of adoption of new ideas. Innovations spread in a population through a process of people talking to others." In the FVSSE our challenge was to create versatile channels for communication about the innovation, which was the use of ICT in science education. Tables 4 to 6 show the channels of communication based on collected data. The tables have been named according to Thompson's (1994) distinction between forms of interaction: face-to-face interaction (Table 4), mediated interaction (Table 5), and quasi interaction (Table 6). These Tables are based on content analysis of the case-study data.

Face-to-face interaction

Plenary lectures. At the beginning of the project, researchers gave lectures on how to integrate ICT in a versatile way in science teaching. They gave an overview and demonstrated several teaching methods such as collaborative work, concept mapping, learning by reading and writing, and practical work in school laboratories. Teachers saw that in principle these lectures were important for further development work. However, some teachers were of the opinion that they were quite familiar with the teaching methods being presented.

I just thought that these lectures were about basic teaching methods. They started from the beginning. What was the objective? Was the goal that everyone speaks the same language? … I think there was a very good repertoire of basic models of teaching, introduced and reviewed. I can't

Table 4. Face-to-face interaction. Case study data were analysed using this categorisation.

Channel of communication	*Description*
Plenary lectures	Teachers, researchers and other experts gave introductory lectures during seminars.
Plenary discussions	Discussions, evaluation, and planning during lectures. Before and after small-group sessions, a researcher led the discussion and wrote memoranda.
Formal workgroups during seminars	Typically, teachers discussed and worked in small groups. Teachers from the same school were encouraged to join different groups. Sometimes groups were formed on the basis of ongoing sub-projects. Teachers were interviewed twice.
Informal discussion groups during seminars	Teachers chatted during lunches, coffee breaks, dinners, excursions, bus journeys, and even in plenary lectures.
Formal workgroups between seminars	Subgroups of teachers from the same school had meetings to plan teaching experiments. In addition, a subgroup of teachers from the capital area planned inter-school experiments. Participating teachers organised local in-service training.
Informal discussion groups between seminars	Teachers on the project in the same school discussed ICT in science education. Participating teachers discussed the topic with other teachers and administrators in their own district. Teachers participated in and communicated with other projects before and simultaneously with the FVSSE.

Table 5 Mediated interaction. Case study data were analysed using this categorisation.

Channel of communication	*Description*
Newsgroup discussion	Between seminars, teachers were asked to write preliminary reports and about their experiences in teaching experiments.
Personal e-mail	Teacher – teacher and teacher – researcher communication.
Course management systems	WebCT was used to plan the inter-school teaching experiment.
Web surveys	Multiple-choice questionnaire (see Table 3) and open questions.

Table 6. Mediated quasi-interaction. Case study data were analysed using this categorisation.

Channel of communication	*Description*
Annual reports	Demanded by the funding institute.
E-post mailing list	Information was easy to send to all participants via a web-form e-mail program.
WWW-based instruction materials	Multimedia for pupils, teaching methods guide, an MBL guide, the home page of the project, and other pages on the Internet.
Publications	Articles in newspapers and in the professional magazine for science teachers.

say that I was aware all of them, even if many of the teaching models were familiar. … Lectures were useful and of high quality. [GA]

There were also teachers, who saw the lectures by researchers to be appropriate and important. Some participating teachers saw – and some did not – the value of the introductory lectures.

As I said earlier, those lectures were super. Like today, concept mapping [given by the second author of this paper]. I had a clue only about concept mapping and we got a lot of theory about it. I had not had time or energy to find material about it. Now, it is seen and we know where to find more on the Net. [GB]

I'm not sure, if they [introductory lectures] need to be so much simplified to this [FVSSE] team. [DA]

Some teachers wanted something else from the lectures, such as one teacher who wanted summaries of the most recent research literature, and another who did not find anything new in the lectures wanted reflection on visions for the use of ICT in science education. A few experts were invited to the seminars to give lectures; they were mainly foreign guests from other projects. Other experts showed up-to-date, high-tech innovations. Some teachers felt that most of the lectures were too abstract or too distant from school practice and teachers even felt anxious about what was expected of them as participants.

The technical aspect [of a learning management system] was too prominent. I'd like to know how to use it. [DB]

Sometimes concreteness and praxis were forgotten. Someone could give a lecture about "what's up" in science education. [NN, open questions, spring 2001]

In the launching seminar, the officer from the National Board of Education spoke with too much complexity and used specific jargon. I'm sure that only about one-third understood something. [GC]

Teachers saw that it was important to formally present, in a lecture format, their experiences from their teaching experiments. Teachers' readiness to take responsibility increased during the project. They presented their experiences and their versions of the innovation. Teachers saw their responsibility and considered the lectures given by their peers very fruitful for the development work.

Teachers are so critical that if we were given a format to proceed – this is the model [to integrate ICT into science education] and that's it – in this project, I'm sure that most teachers would quit. Working models develop all the time and it is wonderful to see how feedback from the previous seminar has been concretised in the current seminar. [GE]

Practical examples [presented by participating teachers] are easy to adopt and further improve on the design. [GF]

During the site visits, the hosts sometimes explained (and the teachers saw) how ICT is used in chemical and physical processes in industry. Unfortunately, some of the introductory lectures before a site visit concentrated on the financial aspects of the operation although the hosts were asked to focus on ICT use. However, teachers found the visits to be important for their work. They could explain something extra – real-world applications of chemical and physical processes – to their students. During seminars, the teachers visited several schools and saw how ICT has been implemented in other municipalities participating in the project. Teachers from the host schools demonstrated their ICT infrastructure. This was interesting to the other teachers.

Our visit to the oil refinery was unpleasant. It was a financial presentation, a good dinner anyway. … Maybe the nuclear power plant visit was most important from the scientific-literacy point of view. [DC]

I most liked seeing how they work in different schools. … It is relieving to see that things are done in a similar way elsewhere. [GH]

It was difficult to find the optimal level for the introductory lectures. Almost always a few teachers thought that the introductory lesson was too difficult, and a few thought that it was too easy. Our intention was to avoid long monologues. We tried to facilitate discussions. Thus, the distinction between a plenary lecture and a plenary discussion is conceptual only.

Plenary discussion. Researchers encouraged teachers to make comments and ask questions during lectures on technical opportunities, technical difficulties, pedagogical values, and any topic they saw as interesting. When someone else was lecturing, researchers asked questions and addressed aspects of the topic relevant to the activities of the FVSSE. Few teachers took part in the plenary discussions; most of them just listened. However, everybody had opportunities to express their ideas in small groups after plenary sessions. They were gradually inspired to participate more and more in discussions. In the evaluation memorandum of the tenth seminar, an unidentified teacher wrote: "We asked plenty of questions [in the plenary discussion during the site visit], more than ever before. We have learned to ask questions." One teacher was disappointed about the lack of feedback. His ideas and teaching experiments were quite radical compared to other teachers' ideas.

The problem is that one can't say clearly: I don't understand you. The critique is hidden in another, wicked form. [GI]

However, teachers positively evaluated the discussions.

The peer group discussion is very important. We have the chance to share ideas, and we get feedback and new ideas. Now we are encouraged by peers to share unsuccessful experiences, too. [NN in final evaluation]

Sometimes a plenary (or small group) discussion theme facilitated generating ideas for other topics.

Now and then, there were plenary discussions and then you get inspiration, something from a sideline, to do that and that while writing notes even if the researcher asks an opinion about the theme of the discussion… [GG]

Still, there were teachers who noticed the importance of the plenary discussions about the topic or about the evaluation and planning of the seminars.

You can get these introductory lectures nowhere. And, if you start to read [books or web materials], you don't get the idea like you get it while discussing in the [plenary or small] group. [GJ]

I respect him [the second author of the paper], how he created the spirit for the project supporting and giving opportunity etc. [GK]

In the end of each seminar, there were discussions about co-operative planning and evaluation. Plenary discussions were arranged before and after formal workgroups and after plenary lectures. During seminars, there was a continuum from plenary lectures through plenary discussions to formal and informal discussion groups.

Formal workgroups during seminars. Typically, teachers discussed how to use some software or promote ICT use in their teaching. They exchanged experiences and redesigned educational innovations and teaching experiments. One important topic in the workgroups was the evaluation and planning of seminars. The teachers wanted more and more small-group working time during the project. They felt that small groups were very appropriate for discussions about innovations, in spite of the ubiquitous lack of time.

It takes a while to create effective group dynamics and to concentrate on the focal point … It's quite seldom that there are only chemistry and physics teachers who get together. You can think and chat on this and that, and everyone understands you. [GL]

The MBL [microcomputer-based laboratory] workgroup showed many aspects I had not understood before. [GD]

This project has given confidence to try many things [innovations related to ICT], first theoretical introductory, then we have collaboratively planned teaching experiments and lastly we have conducted these experiments. [DA]

A few times, we tested a teaching experiment with writing in small groups. It seemed effective, but the teachers did not see reporting to be of such significance that the limited time should be used for that.

In the beginning, we finalised the new material during each seminar. I would not say if reporting is appropriate or not … [GD]

The basic form of the seminars was considered adequate. Plenary lectures and plenary discussions facilitated discussion between the participants on the planning and redesign of the model of ICT, which had been introduced for science education. The seminars included coffee and lunch breaks, and the seminars were held in different locations, so teachers had plenty of time outside of formal proceedings.

Informal small-group discussions during seminars. Teachers continued their discussions about the themes of the previous lectures outside of the lectures. They also discussed general educational themes such as national educational policies, and so on. There were usually at least three locations per seminar: a local school, a site for local industry, and a hotel. Thus, during each seminar, there were ample opportunities to sift through the material. Bus trips in particular were considered very useful. They offered plenty of time to reflect on proceedings and to plan teaching experiments without any pressure to produce something to be presented.

The distance to the steel plant was quite long. It seemed that the long distances to industrial sites was not a handicap. [GH]

The seminars have been very fruitful, even if they are quite intensive. In the FVSSE, we have succeeded in combining effective working and free time. Even free time serves the goals of the project. [NN]

Some teachers hesitated to share their thoughts with everyone. They were sometimes worried that their ideas might not be relevant to the topic. Then they had an opportunity to test their ideas in a small, informal group.

I chatted in the corridor and the general conclusion was that it [learning management system] is not so essential, it does not bring anything new. [GM]

Now and then, we have spoken in whispers; this could be a good idea etc. [GC]

Discussions went late into the night. Themes were typically humorous, but topics hovered around the current seminar or another relevant educational issue such as planning for the next seminar.

The social programme of the seminars was not only for pleasure – we have talked a lot, shared experiences. [GN]

Yes, it [bioenergy plant] would be interesting, but we had to run through all these visits [bioenergy plant, local newspaper, ecological cheese dairy] because there were so many places to see. Well, in the school equipment manufacturing plant we had time to spend the evening. [GG]

While spending time in the lobby, she [DC] phoned the company (with the aim to organise a site visit); it was easy, because she knows the manager so well. [GJ]

Formal workgroups between seminars. Teachers from one school gathered to discuss how to organise teaching experiments. A subgroup of teachers in the national capital area arranged planning meetings.

These meetings with [GD] and others were long-lasting and results were quite [modest], but these meetings stimulated thinking. [GO]

Meetings were excellent; even if the result [inter-school teaching experiment] satisfied almost no one. We had different objectives than the others expected. [GI]

Typically, a few teachers taking responsibility of administrative affairs arranged budget-planning meetings. Overall, teachers rarely met formally (at a mutually agreed time and place) to plan or to reflect teaching experiments (or else they did not inform the researchers about their meetings).

One goal (especially from the point of view of educational policy) of the project was to distribute the results. Teachers organised local meetings where the FVSSE teachers introduced pedagogically meaningful ways to use ICT in science education with their peers in the district.

I organised a training session for about ten teachers on how to use the developed radiation multimedia. [GJ]

Informal small-group discussions between seminars During breaks, teachers talked about teaching experiments, how to use ICT in the school, and how to conduct teaching experiments.

We wonder in the school: what we are expected to do? On the other hand, it helps us to develop the use of ICT. … During breaks, they [two teachers in the same school] worried if this [teaching experiment] was going to work at all. After doing the teaching experiment, they were pleased, and their pupils have given positive feedback. … When we [teachers from the same school] are preparing demonstrations, we talk about the use of ICT, and other topics of the project. … It is an easy way to communicate; we do not have to schedule in advance. [GF]

One teacher found this very difficult, because he was the only physics and chemistry teacher in his school, so he could not discuss the issues with anybody in an informal way. All the other schools had at least two teachers in the project. Despite the number of science teachers in a school, the topics discussed between teachers are often limited.

Well, practical help I have got, mainly we discuss the topic [use of ICT] during seminars. Here [in our school], we have our own topics. [GL]

It has been fruitful to discuss with a colleague [in the same school], what went wrong. [GI]

Other teachers in the same school might ask the FVSSE teachers to say something about the innovation. These discussions could even lead to interdisciplinary co-operation, and some level of subject integration. Teachers helped their colleagues to become aware of ICT in (science) education.

I use web-based instruction material a lot. I try to find applets etc. to show myself and them [other teachers in the school] that in the Web, there is plenty of useful material and I show them ways to use Web materials. [GK]

When chemistry and physics were funded and they were in the spotlight, the status of these subjects rose in the school and in the local administration. Local educational administrators consulted the FVSSE teachers about ICT in education in general.

Our city is buying a learning management system and educational administrators have interviewed me four times to find out what is needed for it. [GC]

In contrast, in the districts without experience with projects like the FVSSE, teachers faced a lot of problems from local administration. The consequence was usually that the teacher who was the link person between school and school administration conducted less teaching experiments. They were very experienced teachers and they were very active in school discussions.

My role in the project [on the school level] is that I communicate with administration and the others understand the topic. [DC]

On the other hand, the differences between the teachers' values and the school's working culture may be too many and too big. Consequently, other teachers may not be interested in the innovation.

We have shared materials [with other teachers]. We have rarely received any feedback. [GA]

We have laughed that we do not have normal office hours in the school, but others do. Thus, we have not pressed our experiences on them. [GN]

Many teachers had participated in a development project before the FVSSE. These teachers were more ready to start new development work. They had experience in how to manage the changes and what is essential in development projects in general. When a teacher participates in one project, it is easier to join another project.

This virtual school project was for the facilitator to say: 'yes, I'll join that project' [chemistry and home economics integration]. [DA]

So perhaps I have joined too many projects, perhaps I should in the meantime develop myself. [DC]

Many teachers participated in other projects in parallel with the FVSSE. Teachers were active in the pedagogical association, in textbook writing, in the national core curriculum renewal project, and in professional development projects or in giving in-service training courses, even at the district level.

Mediated interaction

Newsgroup discussion. Almost all participating teachers wrote and posted reports on their experiences of teaching experiments at least once to the newsgroup of the FVSSE. However, only a small number of teachers were active in the discussion.

The newsgroup, in the beginning it worked quite well. Now it doesn't work. Is it so that the conducted discussion had no consequences? … We have to find a tool for communication between seminars. [GI]

Some teachers felt guilty because they were not actively writing in the newsgroup. On the other hand, the teachers felt that long-distance communication needed improvements and they saw its potential. The teachers suggested that a facilitator was required.

We need more detailed guidelines, it is difficult to give comments if it is not possible to write anonymously. It is also a problem when one does not know with whom they are talking. We need a leader or a facilitator, it is good to comment on others' comments. [NN, Evaluation session in the end of the second seminar]

We have more co-operation, but why there is no functioning discussion in the newsgroup? Obviously, people are not meant to have discussions on a keyboard. Obviously, there was no urgent need for discussion. [NN, the final evaluation discussion]

The newsgroup has not functioned exactly as it was [planned] or I do not know if there were any expectations. Some people have submitted their reports there. Commenting has been restricted to a few people, a faithful few who have written reports there, if they promised to do so. However, they do not write comments. [GG]

When some of the more active teachers posted messages on the newsgroup, the majority of the participating teachers did not comment or give feedback. However, they frequently read the newsgroup postings.

In the beginning, we always circulated the summaries of our formal meetings between seminars, but there were no comments. It is rather difficult to react, when one knows nothing about what other people have thought, said, or written. It is like writing a message in a bottle. Probably somebody will read it, but certainly there will be no *feedback. Although we had a channel for giving feedback, we did not use it. [GI]*

It is easy to read a paper in a newsgroup, but I have it so difficult to write comments like 'Hi, well done!' I could do it but I am not used to do so. Better yet would be 'you could add to it …' or would you mind if I steal your idea and add this …?' It could be a way to create something new in the Net! [GG]

It is so much easier when we are face-to-face during our meetings! [GL]

Teachers felt that writing and making comments on the newsgroup was very difficult. One teacher evaluated the discussion and he felt that it was difficult to decide how much contextual information was needed so that the discussion made sense. He felt that others do not understand his ideas, even when face-to-face.

The problem is how to share all you think. How do you 'say' essentials and how do you show that you have understood others' writing. How do you write facial gestures? How much more writing is needed? … Even during face-to-face discussions, it is quite difficult to get productive feedback. [GI]

Personal e-mail. The teachers planned and evaluated seminars, teaching experiments, and educational ICT innovations. The researchers supported teachers in conducting teaching experiments and with advice on how to write an annual report. A template for teaching experiment reports was prepared to help the teachers in their writing efforts. Teachers preferred e-mailing for mediated communication.

These contacts are created when there are reasons for them. When one has this kind of real co-operation, there are reasons to send e-mail. One does not send greetings here. [GE]

Course management systems. A subgroup of teachers tested and evaluated a course management system to share documents while planning the inter-school teaching experiment. They found it frustrating, because the course management system was too clumsy and the benefits were rather limited. It was easier to build simple web pages or use e-mail attachments.

Furthermore, I'd like to have more co-operation between schools, for instance using user-friendly platforms. [NN, open question in teacher survey 2002]

I have waited for more virtuality … to have virtual contacts with other schools. [DB]

Web surveys. The teachers were also asked to evaluate themselves within the context of the project. They had to reflect on how they understood the innovation and how they evaluated the project and their own adoption of the innovation. The teachers listened very carefully to each others' reflections.

It was a big surprise to receive this questionnaire [on using reading and writing activities]. Perhaps it was why the return percentage was lower than usual, we wondered what this actually is… [GA]

When we filled in the questionnaire, we certainly used less time than you [the researcher] reading it. [NN, feedback for analysis of teacher survey 2001]

Mediated quasi interaction

Annual reports. Teachers reported their experiments and other activities at the school level (Table 1). Researchers polished the annual reports for submission.

E-post mailing list. Mostly the researchers sent information via the e-mail distribution list about seminars, applications, annual reports, and so on, to help in the administration of the project. A group of teachers organising a seminar sent informative e-mail about logistics and other practicalities. A few times, a small number of teachers sent messages to inform the others that they had published something for others to comment on. A few teachers posted messages on the newsgroup, which were distributed using the e-mail list.

I submitted the last request and guidelines for experimenting with the Web materials on nuclear energy. See the newsboard message dated 18th August! We'll meet in Eurajoki. The group from Kiuruvesi will arrive already by Thursday night, so we might go sightseeing. [GJ]

WWW-based instruction materials. A subgroup of teachers was contributing as authors to the design of radiation multimedia produced by the EIO. One teacher who already had an M.Sc. degree completed his Master's thesis for his M.Ed. about design of the teaching materials. Other teachers tested and commented on the multimedia product. We utilised the teachers' reports when we further developed the web-based teaching guide for science teachers. The teachers' reports were available for viewing on the FVSSE homepage. The MBL-guide, developed at our Department was introduced to the teachers. They talked about ready-made simulations and other contents available on the Internet, which could be utilised in science education.

Free, easily-available learning materials, guides for demonstrations and practical work etc. were probably rather useful. [NN, teacher survey, 2002]

If students do a project and find materials on the Internet, the outcome is messy, it does not convince that anybody understood a thing. The Net materials on nuclear energy were produced with intensive effort. And it worked! [NN, final evaluation]

Or the introductory lessons were good enough, but the slides could have been available in the Net so that we could have seen them in advance and used them as background material for discussions. [GO]

There [fourth seminar] we made acquaintance with Applets available on the Internet, they were useful and I have used them in my work. [GA]

In everyday work I have noticed that I need more skills in editing Web pages. Ready-made materials are not necessarily good [for pupils]. The Web server of the City *does not allow easy access, but the door is open. [GI, evaluation memorandum, 10th seminar]*

Publicity. The FVSSE seminars were noticed by local newspapers. The teachers were quite pleased about the increase in public awareness and respect. We wrote articles on how to use ICT in science education based on the teachers' reports, which were published by the pedagogical association of science teachers. Local teachers seemed to be quite satisfied.

Due to the project we have got money and positive publicity in local newspapers. [NN, final evaluation]

DISCUSSION

The purpose of this research was to evaluate the efficiency of communication channels during a project in which subject teachers developed versatile uses for ICT in science education. We particularly wanted to discover how different communication channels appeared to teachers, as how effective they evaluated them, and how the channels seemed to promote the adoption of ICT in science education.

Participating teachers' self evaluation indicated that they had increased their use of ICT in every tested computer application category. Thus, the project appeared successful, and the description of the project can be considered a positive research result, providing features of efficient professional-development projects (see also Lavonen, et al., 2006). The chosen strategy to gradually increase teachers' responsibility for the progress of the project appeared to be an important aspect for the participators' full engagement. Our analysis of communication channels showed the efficiency of face-to-face communication. The interpreted importance of mediated interaction or mediated quasi interaction appeared to be unexpectedly low. An analysis of the face-to-face communication channels indicated that informal communication on the adoption of ICT in science education was surprisingly important. In summary, the present research, which explored communication between teachers about ICT in science education during a three-year development project, indicated that face-to-face interaction are interpreted the most significant form of communication. During informal small-group discussions teachers could share their ideas about pedagogical aspects of the innovation. This perhaps helped teachers to shape their values and attitudes positive towards ICT use in science education.

Teachers participating in the FVSSE identified problems which limited the use of mediated communication similar to those reported by Ferraris, Manca, Persico, and Sarti (2000). One of these problems is the fear of criticism associated with the public and written nature of communication. In the FVSSE, the newsgroup discussion was open to anybody with Internet access. Because the project was publicly funded, openness was required as a matter of policy. Publicly mediated communication was also supposed to help in avoiding criticism that this project were too closed to other than participating teachers. The Internet offered here better tools than what were available to the FINISTE project (Kuitunen, 1996). Our experiences differ with Ferraris et al. (2000) with regards to which tools were used. In the beginning of the FVSSE, the mediated communication channels were the newsgroup and personal e-mail. Participating teachers were familiar with those media. However, teachers frequently indicated a desire for a communication medium only available to participants. Therefore, a subgroup of teachers used a learning management system for collaborative knowledge building in teaching experiment design, but found the tool clumsy. Trainees in the Ferraris et al. (2000) project met face-to-face once a week. Thus, they waited for their face-to-face meetings and ignored mediated communication. We found a similar tendency in the FVSSE. Participating teachers preferred face-to-face communication, even though they only met face-to-face twice each term. Teachers participating in the FVSSE could not overcome the restrictions of mediated communication. Perhaps they did not become familiar with adding contextual information to their newsgroup messages (cf. Thompson, 1994).

Even if it was expected that face-to-face communication would be perceived as more significant than mediated interaction or mediated quasi-interaction, the strong preference for informal discussion groups was unexpected. As described above, the project had many features of a traditional in-service training course in the beginning. A group of teachers, previously unknown to each other, gathered together to listen to lectures and participate in workshops.

We arranged the formal workshops in such a way that teachers from the same school were in different groups. In a free-choice situation, individuals tend to interact with those who are very similar, forming homophilous groups (Rogers, 1995, 19). We expected that participants would share a mutual (science teacher) language and a common understanding, which would ensure effective communication. Thus, we thought that this was enough, and the teachers were not too similar to each other. It turned out that the teachers' views of learning were quite different, their ICT capability varied, and ICT availability differed widely between schools. Therefore, at the beginning of the project, teachers spent coffee breaks, lunches, site visits, and other informal discussion time mostly with their colleagues from the same school. During the project, teachers got to know each other, and they continued working with the formal workgroup themes in informal situations.

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They shared information about the innovation and started to develop their own ideas about it. This change from very homophilous to more heterophilous groups demonstrates the importance of providing a good mix of formal workgroups and opportunities for informal discussions.

Our experiences suggest that opportunities for informal discussion should not be only during breaks in the programme, but that they should be written into the schedule. If, for example, coffee breaks went on too long, teachers might feel the agenda is too loose. The plainest example of the FVSSE might be bus trips. In the seminar held in the city of Oulu, we had a site visit at a steel plant. The visit was the only reason for travelling together by bus (the trip from the city centre to the plant took about one hour). In the bus, two to four persons could easily talk together and continue planning and chatting during the visit. In addition, a social programme easily creates a positive atmosphere. During dinner, it is easy to make silly or unreal suggestions for new innovations. The informal atmosphere of dinners proved to be particularly facilitative in the sharing of information. At these times, teachers often shared their ideas for nationally or locally important aspects of the project. They had a feeling that they could have influence on many levels: at the school level (teachers in the same school), at the district level (core curriculum of the municipality, local projects), at the national level (textbooks, the matriculation examination, renewal of the national core curriculum, pedagogical associations, teacher education) and even at the international level (international surveys such as PISA or ROSE and participation in international conferences). Such ideas encouraged teachers to be active developers rather than passive implementers. They formed a critical, but collegial and supporting, community in which they could share and distribute expertise.

During the journey home, teachers from the same school had plenty of time to discuss and plan teaching experiments. Therefore, the programmes should be attractive and pleasant enough that teachers will repeatedly spend their Saturdays travelling. In the FVSSE, teachers collaboratively planned seminar programmes this way. They even waited enthusiastically for seminar weekends. Finding an optimal itinerary for each programme was important, because content was the reason for teachers to leave their pupils with substitute teachers and even to participate in the whole project.

Although face-to-face interaction appeared to be successful, mediated interaction was not. Experiences in the project indicate that mediated interaction (or mediated quasi-interaction) requires a clear and shared motive for communication. In pre-service training, students can be required to communicate by newsgroups and social media applications, but in in-service training, which is based on the free will of the participants, communication is based on intrinsic motivation. If mediated communication as such is considered important, there has to be some way to stimulate intrinsic motivation. A key could be collaborative development work with clear shared goals.

Another reason for the lack of participation in mediated social knowledge building could be the fact that teachers had to develop ICT in science education while they were still novices with ICT themselves. Even if this was the case, the teachers felt that the efficiency of mediated communication was low: they strongly criticised web pages, newsgroups, platform for knowledge building, and e-mail distribution lists. They talked about how to improve mediated communication without finding a solution. Their general opinion of the web materials was positive, although they rarely studied them before the seminars. This indicates that Internet resources are useful in the right context. These resources should be ready to use, if needs are apparent.

The fundamental goal for the professional development of teachers is that their pupils will learn better. When teachers participate in projects they see as meaningful, they are likely to be more enthusiastic and it is likely to have a positive influence on their students. Teachers were given autonomy in budgeting and in the content of the project: they learned what it was like to be an empowered member of a development project (see Lavonen et al., 2006).

Our intention was to describe the progress of the project in as much detail as possible, in order to ensure the transferability of results. Thus, it could be possible to evaluate how well the project and the conclusions of the present paper correspond with the reader's cultural and educational context. Table 1 and Appendix 1 show a summary of the whole project (cf. Miles & Huberman, 1994, 90–142). The data show the triangulation approach which is one of the essential features of our research project. We report in another context (Lavonen et al., 2006) that the FVSSE was successful in reaching its goals as a professional development project.

The main lesson learned is that professional development projects for teachers should not put too much weight on mediated interaction between teachers. Conversely, the present case indicates that more emphasis should be placed on providing opportunities for informal communication.

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Appendix 1. Contact meetings (seminars) of the FVSSE. Key issues derived from the case study data and interpretation of the effect of the key issue for the progress of the project

Seminar	*Key issues*	*Interpretation and comments*
2000		
Launching seminar	The EIO sponsored the preliminary seminar. The project application was drawn up in the seminar.	Many teachers were very confused. Neither they nor the researchers knew what to expect. The project had features of in-service training.
Seminar 1 [Tampere]	In the first seminar, distance tasks were distributed to the teachers. The first development area was learning by reading and writing. Preparation of the training fund application so that the researchers could travel, and thus participate in seminars as "trainers".	Many teachers were anxious. Lectures given by outsiders (researchers from the Technical University of Tampere) seemed to be too abstract and introduced innovations too radically. On the other hand, some teachers found the lectures very interesting.
Seminar 2 [Oulu]	The first industry visit to the hi-tech company. Introductory lecture of the first survey. Finalising the reports of the teaching experiments and reflecting present teaching practices in small collaborative groups. Discussion of the first survey of the teachers' and students' ICT competence and use of ICT in science education	The working model of the project was ready. The first day of the seminar in the company offered lunch, coffee, and dinner and free use of seminar halls. Second day, Saturday, in the local school: Short lectures and working in collaborative groups and reflections.
Seminar	Key issues	Interpretation and comments
2001		
Seminar 3 [Helsinki – Vantaa]	The second area for development was ICT in practical work. Visitors from Scandinavian and Baltic countries introduced ICT instruction materials.	There were too many visitors. The schedule was too tight and people felt they had to hurry all the time. The discussion was not very reflective, although it took place in small groups.
Seminar 4 [Kauhajoki]	A participating teacher gave an introductory lecture for the first time (on the use of Java applet simulations in physics education). A template for teaching experiment reports was introduced to the teachers. The hosts introduced development projects underway in the municipality. Progressive inquiries using learning management systems.	Teachers from urban areas (Helsinki, Vantaa, and Oulu) saw that in the rural area, there were high-quality development projects in education and in industry. Some of these projects were financed by EU structural funds.
Seminar 5 [Eurajoki]	Teachers' presentations of their development projects at the school level. Introductory lectures about the teachers' self-evaluations of the first year of the FVSSE. A subgroup of teachers started to collaborate to develop inter-school teaching experiments. Visit to the nuclear power plant.	Teachers saw how peers had interpreted and implemented ICT in science education (ICT in reading and writing, practical work, and distance learning). Teachers concentrated in one or two development areas. Researchers' role was to help teachers conduct teaching experiments.
Seminar 6 [Kiuruvesi]	The teachers were responsible for the programme. The first long distance bus drive to the site visit. Introductory lecture about collaborative work by a local teacher (PhD in education and the principal of the school).	During the bus trip, a subgroup of teachers decided to start designing a collaborative teaching experiment using WebCT. Distance communication was frequent during the winter.

Seminar	*Key issues*	*Interpretation and comments*
2002		
Seminar 7 Helsinki	Co-operation with the EIO to further design radiation multimedia (www.tat.fi/2003/nuoriso_ja_koulupalvelu/verkkokoulu_ydinasiaa.shtml). Teachers presented the results of their collaborative teaching experiments. Long bus drive to the location of the site visit.	The presentation at the site visit was financially oriented. Thus, it did not meet the interests of the teachers, which are ICT in industry or physics and chemistry in the industrial processes.
Seminar 8 Oulu	Site visit to a steel plant and a dinner in the plant's reception room. Preparing reports on the teaching experiments. Long bus trip to the site visit. Two teachers prepared a poster for an international conference See www.girep.fysik.lu.se/abstracts/abs	The teachers recognised the uniqueness of the project. There were textbook writers, members of the Committee for Renewal of the National Core Curriculum, etc. Over sixty per cent of the teachers also participated in some other project.
Seminar 9 Vantaa	Teachers from the city of Vantaa organised a reflective discussion about the project. Teachers presented their focus areas (use of modelling in chemical education, video editing). A visitor from Israel presented a web-based instruction project.	The researcher's role was to participate and to write the memorandum. Teachers recognised that the project seemed to meet high international standards. Teachers had taken the responsibility of the project from the planning to the reflection phase.
Seminar 10 Kauhajoki	Teachers from the city of Kauhajoki organised a programme showing the wide variety of ongoing educational development projects in the district. Long bus trips.	Local development projects offered issues for teachers to reflect on in informal groups during bus journeys. Researchers were needed to help teachers in their critical reflection.
Seminar	*Key issues*	*Interpretation and comments*
2003		
Seminar 11 Eurajoki	Presentations of the ICT innovations. Planning the distribution of the project results.	Teachers saw themselves ready to organise local in-service programmes. Teachers planned a subsequent project for FVSSE.
Seminar 12 Kiuruvesi	The last seminar. Visiting a brewery and a hi-fi speaker factory. Planning the dissemination of the project outcomes. The final self-evaluation of the project.	Planning the distribution of project results. A subgroup of teachers decided to apply for further funding for a project where subject teachers would help class teachers start to teach physics and chemistry. This was important since the renewal of the Finnish National Core Curriculum will introduce physics and chemistry to be taught in primary schools.

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Considering Material Development Dimension of Educational Technologies: Determining Competencies and Pre-Service Teachers' Skills in Turkey

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The purpose of this study is to develop a list of competencies for the undergraduate level new educational technology course considering material development dimension in Turkey. Also, it was investigated to what extent pre-service teachers in Turkey gained these competencies. A total of 2,460 usable surveys were analyzed. It was found that male and female students received similar scores with similar standard deviations. The results also showed that students' competency levels in the elementary teaching programs were significantly higher than those in the other teaching programs, except the preschool teaching programs. On the other hand, students' competency levels in the elementary mathematics teaching programs were significantly less than students' competency levels in the other teaching programs.

Keywords: Educational Technology, Technology Competencies, Material Development

INTRODUCTION

Technology has a significant impact on our society, and has become a permanent part of our schools and classrooms. In this new era, teachers should have at least minimal educational technology proficiencies. However, due to rapid changes in technology, educational researchers have been challenged to answer a critical question: What are the educational technology knowledge and skills teachers should have? In order to answer this critical question it is important to examine research studies that have been conducted to determine different dimensions of educational technology competencies that teachers/instructors should possess.

Educational technology knowledge and skills have been perceived differently in different studies. From one perspective, it is generally considered that some computer and hardware skills teachers should have are educational technology skills, such as (1) creating, naming, saving, retrieving and revising documents, and using print options, (2) setting up and operating a VCR and monitor/TV, (3) applying strategies for identifying and solving routine hardware and software problems that occur during everyday use, (4) evaluating software and technology for instructional use, (5) creating spreadsheets to manage information, (6) creating databases to manage information, (7) setting up and operating a presentation system that works with a computer, (8) producing electronic slides/overheads and (9) developing web pages and/or sites for instructional use and relating information to parents (Ku, Hopper, & Igoe, 2001).

A study by Tsao (1998) investigated secondary vocational teachers' educational technology competency needs. The results showed that secondary vocational teachers rated educational technology skills important or very important that are related to using some hardware and computer software such as using an overhead projector, using word processing and spreadsheet

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software, using an operating system, downloading programs through the internet and creating multimedia presentations.

Instructional Technology Passport System (ITPS), developed by Technology Learning Circle (TLC) group of Illinois State University, was designed to ensure that graduating teacher candidates are able to use instructional technology in effective ways in compliance with national, state and institutional standards. Instructional technology competencies of the ITPS include the ability to use technology to work effectively and equitably with students challenged by a variety of physical disabilities, understanding basic computer terminology, concepts, and operation, the ability to use varieties of instructional media effectively (DVD/CD player, digital still camera, etc.), the ability to create and edit the content of web pages and the ability to use presentation authoring tools, idea development software and desktop publishing (Braun et al., 2002).

A different study by Scheffler and Jogan (1998) investigated what computer competencies public school teachers needed. In this study, using the Delphi technique and survey method, 67 computer competencies rated important or very important by teachers were identified. Most of these competencies were related to hard computer skills such as using a computer keyboard and operating computer hardware and software to troubleshoot minor problems. However, limited attention was also given to pedagogical skills, including using software to facilitate instruction and evaluating the effectiveness of computer-supported instruction.

As an educational technology skill, Hofer and Whitaker (2002) particularly emphasized using a variety of software programs in instruction. They proposed educational technology competencies with two dimensions. In one dimension, the competencies were classified as practical, innovative and future, in the other dimension, standard driven, depth/creativity and transforming education. Between these two dimensions, teachers should learn to use certain software programs for word processing, drill and practice activities, preparing and using multimedia presentations, designing web pages, collaborating on the internet, creating electronic portfolios, designing WebQuest, conducting internet searches, designing concept maps, performing inquiries with mind tools and creating digital videos, animations and 3D modeling.

The definition and focus of educational technology have changed over the years. In a recent definition, educational technology was regarded more as pedagogical skills to solve learning or performance problems, rather than being able to use hardware such as computers and projection machines (Reiser & Dempsey, 2002). Supporting this view, it is important to see in the recently identified teacher technology competencies that there has been more emphasis on the skills related to instructional uses of technology than to the skills related to hardware and software operation. Hence, teacher technology proficiency should be considered multi-dimensional, and the question "What must teachers know about using technology in the classroom?" should be answered in the context of different sets of knowledge and skills that effective teachers possess (Gooler, Kautzer, & Knuth, 2000).

For instance, besides the two categories that are prerequisite technical skills and technical skills underlining the use of all computer and related technologies, Moore et al. (1999) suggested two additional major educational technology competency categories that included pedagogical skills for teachers: instructional uses of technology applications to improve learning and professional activities, and behaviors teachers must use in an information-age classroom. Similarly, Albee (2003) concluded that educational technology competencies should include, besides technical skills, pedagogical skills such as evaluating and selecting software, developing instructional activities with computer software programs, integrating computer technology into teaching, and awareness of technology's ethical and legal issues.

Putting more emphasis on the skills related to instructional uses of technology rather than skills related to hardware and software operations, the most comprehensive approach to determining educational technology competencies may be seen in the NETS-T (National Education Technology Standards for Teachers) Project of the ISTE (International Society for Technology in Education). This project classified technology competencies under six categories: (a) technology operations and concepts, (b) planning and designing learning environments and experiences, (c) teaching, learning and curriculum, (d) assessment and evaluation, (e) productivity and professional practice and (f) social, ethical, legal and human issues (Gooler, Kautzer, & Knuth, 2000). This comprehensive approach can also be seen in cross-cultural/international settings (Schiller, 2002; Laanpere, 2001).

The Higher Education Council of Turkey restructured its teacher education programs in 1998. Under the new program all pre-service teachers in their third year were required to take a new educational technology course named Educational Technologies and Material Development. It may be perceived that the content of the new technology course may be similar to other contemporary educational technology courses. However, it additionally considers a new dimension in educational technology: material development.

The description of the new course in the program manual reads as follows: "Features of several educational technologies, their use and place in the teaching process, developing teaching materials (work sheets, transparencies, slides, videos and computer-based course materials) by using educational technologies and evaluating them." No further explanations or competencies were provided for the course.

The purpose of this study is to develop a list of competencies, agreed upon by educational technology experts, for the new educational technology course considering material development dimension. Also, it will be investigated to what extent pre-service teachers in Turkey gain these competencies.

This research study has three objectives:

1. Determining educational technologies and material development competencies
2. Determining to what extent pre-service teachers in Turkey possess these competencies
3. Investigating the differences in pre-service teachers' possessing these competencies by gender and teaching programs

METHOD

Survey Instrument Development

A 46-item practical educational technology and material development competency survey instrument was developed by the researchers and sent to 2,600 pre-service elementary teachers in Turkey.

After reviewing related textbooks and documents, an initial list of 217 general educational technologies and material development competencies was developed and categorized into eight sections: (1) general concepts and definitions in educational technologies, (2) educational technologies and communication, (3) designing materials for instruction, (4) distance education, (5) using computers in education, (6) education and the internet, (7) planning educational technologies, (8) learning theories and (9) evaluation. A three-round process was planned to evaluate and refine the initial list. The evaluation was performed by a group of educational technology experts.

Members of the expert group were selected among university professors in the educational technology departments of colleges of education in Turkey. Each holds a Ph.D. degree in the educational technology field. A total of 15 experts were contacted via phone; 10 of them agreed to participate in the three-round evaluation process.

In the first-round evaluation, the list of 217 competencies was sent to the experts. They were requested to examine competencies and recommend additions, deletions, categorizations and rewordings. They were also requested to rate the importance of each competency using a 5-point Likert scale: (1) not important, (2) somewhat important, (3) moderately important, (4) important and (5) very important.

After the first-round evaluation, the second competency list was created based on the experts' ratings and recommendations. This competency list included 239 items receiving a mean rating of 3 or higher (moderately important, important or very important) plus new competencies suggested by the experts. Also, wordings of some items were changed. The second competency list was sent to the experts for the second-round evaluation.

In the second-round evaluation, the experts re-rated each competency, but they made no recommendations for any additions, deletions, categorizations or rewordings. Because the content of the second competency list was not changed in the second-round evaluation the third round-evaluation was not performed.

The final competency survey, with 227 items, was created from those competencies receiving a mean rating of 3 or higher (moderately important, important or very important) in the second-round evaluation. Based on ratings by the experts, calculation of Cronbach's alpha reliability coefficient of the final survey is 0.97.

The final competency survey had a large number of items and was to be administered to a large number of pre-service teachers. This caused a concern about pre-service teachers' possible unwillingness to participate in the study, reluctance in responding to the survey items and difficulties in administrating the survey. Therefore, the 227-item educational technology and material development competency survey was reduced to a new 46-item practical educational technology and material development competency survey.

The new survey was intended to collect information on pre-service teachers' practical or application-based educational technology and material development competency levels. Application-based competencies are defined as the ability to use previously learned information and skills in new situations to achieve a goal. Some of the application-based competencies in the new survey are: being able to prepare simple learning materials that are original and economical, using readily available resources and environmental conditions, being able to properly use flipcharts in lessons, being able to properly use overhead projectors in instruction and being able to teach a lesson using instructional techniques appropriate for the skill/subject to be taught.

Knowledge-based competencies, on the other hand, are those that emphasize remembering or recalling rules, facts, terms, trends and sequences. Some of the knowledge-based competencies that were not included in the new survey are being able to define technology, being able to explain historical development of technologies used in education, being able to explain the benefits of using instructional materials in the classroom and being able to explain why learning environments should be arranged.

Pre-service teachers rated their practical educational technology and material development competencies using a 5-point Likert scale: (1) I do not know enough of this competency to respond, (2) I don't have this competency, (3) I am not sure, (4) I have this competency and (5) I definitely have this competency.

Population and Participants of the Study

The population of this study was senior elementary education students from all of the 61 colleges of education in Turkey that had elementary education departments, training teachers for grades between first and eighth. A typical elementary education department of a college of education in Turkey has five teaching programs: elementary, social science, elementary mathematics, science and preschool. The elementary teaching programs train teachers for basic education for grades between first and fifth. The other teaching programs, except preschool, train teachers for a specific subject area education, i.e., mathematics, social science or science, for grades between sixth and eighth.

According to data retrieved from the Higher Education Council's website, there were approximately 16,685 senior elementary education students in Turkish colleges of education when the data was collected in 2006. Distributions of students by the teaching programs was as follows: 7,715 students in the elementary teaching programs, 2,700 students in the social science teaching programs, 2,080 students in the elementary mathematics teaching programs, 2,505 students in the science teaching programs and 1,685 students in the preschool teaching programs. A total of 2,600 survey questionnaires, corresponding to 15.6% of the total senior elementary education students, were sent to 13 randomly-selected colleges of education that have an elementary education department.

Data Collection and Analysis

The students' responses were collected by mail. Before the mailing, a contact person was chosen from each of the 13 colleges. They were informed about the research study and requested to help administer the survey in their institutions. Then a packet was mailed to the contact people that included survey questionnaires, optical answer sheets, a stamped self-addressed envelope and instructions on administering the survey.

Descriptive statistics were used to summarize the means and standard deviations of 46 competencies. Also, t-test and Analyses of Variance (ANOVA) were employed to determine whether significant differences existed in students' competency levels by gender and by teaching program, respectively. The alpha level was set at .05.

RESULTS

A total of 2,460 usable surveys, corresponding to 94.6% of the total participants and 14.7% of the total population, were returned. The calculated alpha reliability of the survey was .95.

The data revealed that students received a mean score of 177.04 (23.9) on the overall survey. More specifically, students received a mean score between 2 and 2.99 on three competencies, between 3 and 3.99 on 25 competencies and between 4 and 5 on 18 competencies.

The practical educational technology and material development competency survey was originally written and administrated in Turkish. Hence, it was not shown in a table format that illustrated descriptive data for each item.

Those three competencies receiving maximum mean scores were related to using search engines (such as Google or Yahoo) on the internet, using overhead projection machines and using models and real materials to teach. On the other hand, three competencies receiving minimum mean scores were related to planning or implementing distance education over the internet or other means.

The means and standard deviations by gender and by teaching program are presented in Table 1 and Table 2, respectively. Over half (56%) of the respondents were female. Male ($M = 176.7$, $SD = 23.5$) and female ($M = 177.3$, $SD = 24.3$) students received similar mean scores with similar standard deviations.

Students' mean scores by teaching program are summarized in Table 2. As can be seen , students in the elementary teaching programs ($M = 181.5$, $SD = 22.1$) received the maximum and those in the mathematics teaching programs ($M = 170.1$, $SD = 21.8$) received the minimum mean score.

Results of t-test analysis showed that male and female students' mean scores were not significantly different ($p > .05$) (see Table 3).

As illustrated in Table 4, a statistically significant difference existed in students' scores by the teaching programs, which means that at least the mean score of students in one teaching program was significantly greater or lesser then the mean score of students in another teaching program(s).

Table 1. *Descriptive statistics results by gender*

Gender	N (%)	Mean	SD
Male	1084 (44%)	176.7	23.5
Female	1376 (56%)	177.3	24.3

Table 2. Descriptive statistics results by teaching programs

Teaching Program	N (%)	Mean	SD
Elementary teaching	617 (25.0%)	181.5	22.1
Preschool teaching	383 (15.6%)	179.2	26.5
Social Science teaching	585 (23.7%)	177.2	23.4
Science teaching	444 (18.0%)	175.5	25.3
Mathematics teaching	431 (17.7%)	170.1	21.8

Table 3. t-test summary table for students' competency scores

Groups	N	Mean	SD	df	T	p
Male	1084	176.7	23.5	2458	.65	.52
Female	1376	177.3	24.3			

Table 4.ANOVA results for students' competency levels by teaching programs

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	69298.0	12	5774.8	10.5	.00
Within Groups	1343704.7	2447	549.1		
Total	1413002.8	2459			

Table 5. The Tukey-HSD analysis results for multiple comparisons of teaching programs

Teaching Programs	(1)		(2)		(3)		(4)		(5)	
	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*
(1) Elementary teaching			2.3	.57	4.3	.01*	6.0	.00*	11.4	.00*
(2) Preschool teaching					2.0	.69	3.7	.16	9.1	.00*
(3) Social Science teaching							1.7	.78	7.1	.00*
(4) Science teaching									5.4	.01*
(5) Mathematics teaching										

MD: Mean difference, * statistically significant.

The Tukey-HSD multiple comparison procedure was used to ascertain which pairs of the teaching programs differed significantly. It was found that students' competency levels in the elementary teaching programs were significantly higher than those in the other teaching programs, except the preschool teaching programs. On the other hand, students' competency levels in the elementary mathematics teaching programs were significantly less than students' competency levels in the other teaching programs. The Tukey-HSD multiple comparison results are summarized in Table 5.

DISCUSSION

Some computer skills and being able to use these skills in instruction are commonly considered educational technology competencies (Kotrlik, Harrison, & Redmann, 2000). However, the educational technology definition by Reiser and Dempsey (2002) points out that the purpose of educational technology is to improve students' learning performances in instructional settings, regardless of using specific means. Computers or any other particular technologies are not specifically mentioned in the definition to achieve this purpose. Therefore, any means or being able to use these means to improve learning performance, such as custom-made instructional materials (Ingram, 1996), can be considered within the realm of education technology competencies.

The questionnaire items rated as moderately important, important or very important by the experts and used in this study supported this view. Only 13 items out of 46 included computer-related skills, such as being able to create multimedia presentations by using computer technology or software. The other items included non-computer-related skills, such as preparing overhead projection slides and knowledge maps. This illustrates to a reasonable degree that educational technology competencies should include skills related to material development.

The results of this study showed that male and female students' educational technology and material development skills are comparable. No significant difference was detected between their skills. However, in other similar research studies, it was not unusual to see that male students had better educational technology skills than female students. One possible reason might be that the survey instrument used in this study had relatively fewer items related to computer skills.

In general, males are considered more technology-, especially computer-, savvy than females (Whitely, 1997; Busch, 1995). Therefore, studies taking particular computer-related educational technology competencies into account may show significant differences in favor of males. Yet this study included only 13 computer-related competencies out of 46. The other competencies consisted of different skills. Thus, a non-significant difference between male and female students' competency levels can be expected.

Pre-service teachers in elementary teaching programs rated their skills significantly higher than those in the other teaching programs, except preschool teaching programs. On the other hand, pre-service teachers in mathematics teaching programs rated their skills significantly lower than the other pre-service teachers.

Considering that different teaching programs use different curricula to train pre-service teachers for different student age groups, these results appear to be logical. According to Piaget, until 11 years of age, children are in the concrete operations stage where they have difficulties in understanding abstract concepts (Driscoll, 1994). To know or understand a concept, children in this stage have to act on it, modify it or transform it, but looking at it or copying it will not be enough to learn it. On the other hand, children between 11 and 15 years of age are in the formal operations stage where they can use reasoning and understand abstract concepts without utilizing concrete objects.

Pre-service teachers in elementary teaching programs are trained to teach elementary school students between ages 7 and 11 that are in the concrete operations stage. Therefore, it is possible that the curricula of elementary teaching programs, especially the courses related to teaching and learning, may emphasize the importance of using technology and instructional materials to facilitate learning of abstract concepts. Thus, students in these programs might already have high motivations and positive attitudes towards using technology and materials in instruction. This might better help them gain skills in the educational technology and material development course.

Pre-service teachers in preschool teaching programs, trained to teach children ages between 3 and 6 that are also in the concrete operations stage, received the second-highest mean score, although it is not significantly different from the mean score of those in social science teaching programs, which is the third-highest mean rating. This may also be a reason to consider the effects of the curricula of teaching programs on pre-service teachers' educational technology and material development competency levels.

Even stronger evidence for the effects of the curricula of teaching programs comes from the result that pre-service teachers in mathematics teaching programs rated their skills significantly lower than the other pre-service teachers. Pre-service teachers in mathematics teaching programs in Turkey are trained to teach mathematics to elementary education students with ages between 12 and 15 that are in the formal operations stage. These students are able to understand abstract mathematical concepts without tangible representations. Furthermore, mathematics usually includes abstract topics and concepts that may be difficult to teach in tangible ways. Therefore, it is possible that the curricula of elementary teaching programs do not emphasize the importance of using technology and materials to facilitate learning, so pre-service teachers in these programs might already have low motivation and attitudes toward using technology and instructional materials in the classroom. This might negatively affect mathematics pre-service teachers' learning performances in the educational technologies and material development course.

The results of this study were based on data obtained from a large number of samples randomly selected from among all of the senior pre-service elementary education teachers in the colleges of education in Turkey. Therefore, the results can be generalized throughout Turkey.

It must be realized that contents of educational technology courses for pre- and in-service teachers should be revised to include material development competencies. Knowledge of these competencies may enable them to be effective in the classroom teaching.

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Ability of Slovakian Pupils to Identify Birds

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A pupil's ability to identify common organisms is necessary for acquiring further knowledge of biology. We investigated how pupils were able to identify 25 bird species following their song, growth habits, or both features presented simultaneously. Just about 19 % of birds were successfully identified by song, about 39 % by growth habit, and 45 % of birds were identified when pupils were allowed to hear their song and to see their growth habit simultaneously. Statistically significant correlation was found between visual and acoustical identification success which suggests that these two stimuli have an additive effect. This study provides direct support for the use of visual and acoustic features of animals when learning about birds in biology lessons.

Keywords: Bird, Biology Education, Identification, Taxonomy

INTRODUCTION

Environmental protection is one of the most important current issues and will only become more important as environmental problems such as the greenhouse effect, forest clear-cutting, and/or human population continues to increase (Erdogan, Kostova, & Marcinkowski, 2009). Environmental knowledge is an essential precursor of attitude formation (Kaiser, Wolfing, & Fuhrer, 1999). Kellert and Westervelt (1984) noted that the level of knowledge is one of several factors affecting attitudes in children. Environmental attitudes consequently influence environmental behavior which is an expected product of a successful environmental education program (Iozzi, 1989). Schools can play an important role in the formation of children's environmental knowledge and attitude (Barraza & Walford, 2002; Prokop, Tuncer, & Chudá, 2007b).

Pupils' knowledge about native animals and plants has been found to be inconsistent (Strommen, 1995) or even limited (Paraskevopoulos, Padeliadu, & Zafiropoulos, 1998). Moreover, it seems that pupils are more interested in pets or garden plants than in wild animals and plants (Paraskevopoulos et al., 1998; Lindemann-Matthies, 2005).

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Knowledge of taxonomy is a basic part of biology. Basic knowledge of (names) of common, as well as, some rare organisms can be considered necessary for further development of biology/environmental knowledge (Randler, 2008). Pupils' knowledge of naming organisms is limited mainly to plants (Bebbington, 2005), and little is known about pupils' abilities to name birds (Randler, 2008; 2009).

Slovakian 6th graders (age 11/12) are learning zoology of vertebrates and invertebrates. They should be able to identify common native animals, to know their anatomy, morphology, and ecology. In contrast to plants, birds can be identified both through song and/or habit. Bird growth habit is the only feature which can be used when using biology textbooks as a learning tool, but supplementary material on CDs or MCs may also include bird song which can be used as supplementary material in traditional biological settings. Bird song might interact with pupils' personal knowledge of birds, and thus the effectiveness of pupils' learning about birds would increase. This relationship is quite important because formal knowledge about animals is associated with attitudes toward them (e.g. Prokop & Tunnicliffe, 2008; Prokop, Kubiatko, & Fančovičová, 2008). However, the role of bird song in pupils' abilities to identify birds has never been examined.

In this study, we manipulated bird growth habit and bird song to test Slovakian pupils' abilities to identify native birds. Moreover, we compare these abilities between elementary school children (age 10 – 15) and university students (biology majors) in order to investigate how basic knowledge of naming birds changes as the age of pupils increases.

METHODS

Participants

A total of 154 pupils from one elementary school (Žilina) (N = 110 pupils) and from one university (Faculty of Education, Trnava) (N = 44 students) participated in this study. Elementary school pupils were 10 – 15 year old (mean age = 12.3, grade 5 – 9), with the same proportion of boys and girls (55/55). University students (38 girls and 6 boys) were 2nd year students with the mean age of 21.2 years. All of them have been studying to become elementary and secondary school biology teachers. During the time that the experiment was conducted (November – February 2005/2006), none of the students had experience with any vertebrate zoology course taught at the university. These two distinct samples of students were chosen to investigate whether age of pupils influences their abilities to identify birds. It would be expected that experiences with birds increase linearly with age of pupils. If so, older pupils (here university students) should have better abilities to identify birds compared to younger pupils.

Analysing Process

We separately examined the effects of visual and acoustical stimuli (bird song and habit), and simultaneous effects of acoustical and visual stimuli on pupils' abilities to identify birds. Both elementary and university pupils were randomly assigned to three treatments: 'Song', 'Picture' and 'Song + Picture' treatment (Table 1). Pupils in Song treatment were allowed to identify typical songs of 25 bird species (acoustic identification) and then pictures (visual identification) of the same 25 bird species. A reverse procedure was used in Picture treatment, where pupils were first allowed to identify bird pictures, and bird song immediately after. These two treatments were conducted in order to minimize potential effect of sequence of identification of method (visual and acoustical) used in the experiment. Bird species used either for acoustic or visual identification were the same, but the order of the species presented visually was different than the order of birds presented acoustically. Pupils were not told about the similarity of bird species used for visual and acoustical identification. This was done in order to maximize the pupils' effort to identify birds independently from the previous treatment. As could be expected, statistical analyses failed to reveal any differences in pupils' identification success between these two treatments, therefore pooled data from Picture and Song treatment were used in further analyses. Also, pupils from these two treatments were presented as a single sample consisting of pupils that identified birds either visually or acoustically.

Implementations

Pupils from Song + Picture treatment were allowed to identify 25 bird species used in previous treatments following their visual and acoustic features, and these were presented simultaneously. Bird identification was conducted in each treatment for a single occasion. Randomly chosen pupils from the elementary school and a whole sample of all second year university students individually used a personal computer in a separate classroom in which presentation of bird species (either visual or acoustical) was started. The length of presentation of each bird species was the same (approximately 60 seconds), and the presentation was repeated once. Each pupil received either two (Song + Picture treatment) or three (Picture, Song treatments)

Table 1. Distribution of participants within experimental treatment groups. Values denote the number of participants.

School		Grade					
	Treatment	5	6	7	8	9	Total
Elementary	Song, than Picture	6	12	9	8	6	41
	Picture, than Song	6	8	7	9	6	36
	Song + Picture	6	10	5	3	9	33
	Total	18	30	21	20	21	110
University	Song, than Picture	-	-	-	-	-	14
	Picture, than Song	-	-	-	-	-	19
	Song + Picture	-	-	-	-	-	11
	Total	-	-	-	-	-	44

sheets of paper with questions which ascertained several details such as age, grade, or gender on the first sheet. Following sheet(s) of paper contained numbers and columns in which bird species were noted by the participants in accordance with whether they were identified by song (sheet 2) or by picture (sheet 3) or by both stimuli (only sheet 2 for Song + Picture treatment).

The pictures and songs of birds were taken from the CD of the original publication of the Ministry of Education, Slovak Republic (Živá príroda, 2001). This publication was originally developed as supplementary didactic material for teaching biology in Slovakian elementary or secondary schools and contains sounds of 90 animals including insects, amphibians, birds, and mammals and approximately a similar number of animal pictures. Pictures of birds contain both male and a female (except species in which sexual dimorphism is weak, e.g. goldfinch *Carduelis carduelis* or the black-billed magpie *Pica pica*) and an egg of each particular species. Almost all presented birds except the black stork, kingfisher and eagle owl can be considered relative common in Slovakia (Danko, Darolová, & Krištín, 2002).

RESULTS

Consistency of pupils' responses

Each pupil's success at bird identification was binomially coded (true = 1, false = 0) which allowed us to calculate the consistency of pupils' responses. Data from both university and elementary school student samples were pooled for the subsequent analysis.

Cronbach's alpha coefficient commonly used for calculation of reliability (Nunnaly, 1978) showed a relatively high consistency just for the Picture ($\alpha = 0.66$) and Song + Picture ($\alpha = 0.67$) treatments. In contrast, Song treatment showed the lowest consistency of pupils' responses ($\alpha = 0.38$). These values suggest that pupils were relatively more certain when looking at bird pictures than when only hearing the bird song.

Acoustical versus visual identification of birds

Figure 1 shows the distribution of pupils (pooled data from elementary school and university sample) that successfully identified birds acoustically, visually, or in combination of both stimuli (acoustically + visually, Song + Picture treatment). Most pupils identified only about 10 – 28 % of 25 bird species when hearing only its song. In contrast, the majority of pupils were able to identify about 30 – 48 % of all birds following their pictures being shown. Interestingly, pupils from the Song + Picture treatment group seem to be most successful, because most of them identified 48 – 60 % of birds. More detailed data is shown in Appendix A. While mean identification success following bird song (pooled data from Picture and Song treatment) was about 19 %, identification success following bird pictures (pooled data from Picture and Song treatment) was 39 % and Song + Picture treatment (i.e. combination of acoustic and visual features) had a 45 % success rate.

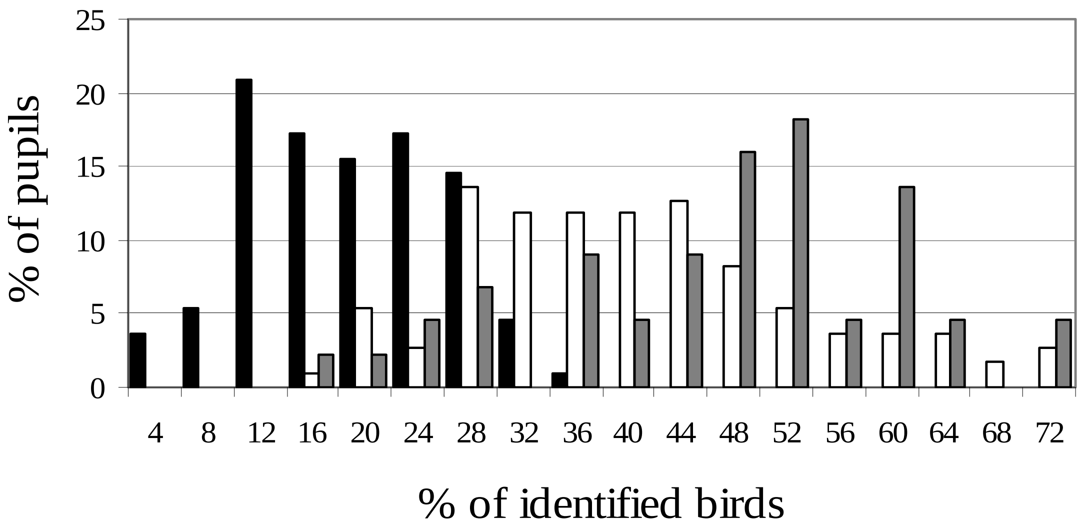

Figure 1. Distribution of pupils that successfully identified birds following song (black bars), pictures (open bars) or both song and picture (grey bars). Pooled data from elementary school and university samples are shown.

Only two birds were better identified by song than by the picture (cuckoo and crow). 7 of 25 birds were significantly better identified in Song + Picture than only from pictures: blackbird, hooded crow, turtle dove, cuckoo, sky lark, black woodpecker and black-headed gull. This would suggest that acoustic stimuli partly supply visual stimuli which explain the relatively higher success in bird identification for Song + Picture treatment where combination of visual and acoustic stimuli was used.

The best known bird species identified only visually were woodpecker, house swallow, black stork and great tit (all were identified by more than 80 % of pupils) (Appendix A). Surprisingly, notoriously common birds such as the magpie, blackbird, and kestrel were unknown to about two-thirds of participants. The

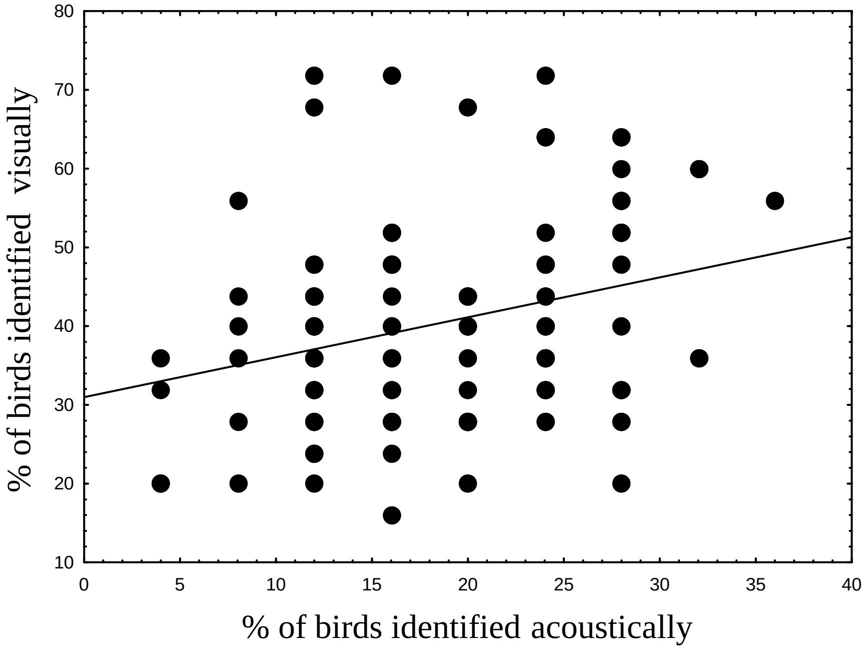

Figure 2. Linear relationship between pupils' abilities to identify birds following acoustic and visual stimuli (r = 0.31, y = 30.9773 + 0.507x, p < 0.001, n = 110).

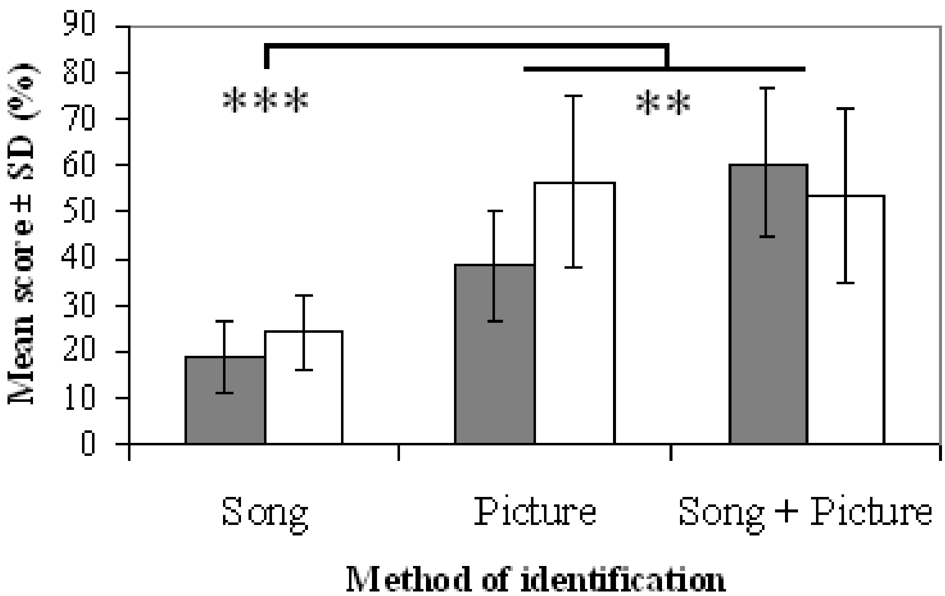

Figure 3. Mean differences in bird identification success with respect to type of school and method of bird identification. Elementary school denotes grey bars, university denotes open bars. Differences were calculated by ANOVA. ** $p < 0.01$, *** $p < 0.001$

sympatric black blackstart and multicoloured goldfinch were virtually unknown. Moreover, about 30 % of pupils failed to identify the house sparrow, which is sympatric, probably the most common bird in Slovakia. Slovak names of birds are strictly binomial. It is also important to note that pupils were generally unable to provide both names of identified birds.

In order to examine whether any relationship between pupils' abilities to identify birds following visual and acoustic stimuli exists, we performed a calculation of correlation coefficients between each pupil's visual and acoustical success within Song and Picture treatments. Song + Picture treatment was omitted, because only one set of data were obtained. Figure 2 shows that the relationship between pupils' abilities to identify birds following acoustic and visual stimuli is significant ($p < 0.001$). This suggests that pupils' abilities to identify birds through visual or acoustic features are not mutually exclusive, and their additive character could explain a relatively better success rate of pupils from the Song + Picture treatment, where both acoustic and visual stimuli have been presented simultaneously.

Elementary school versus university: is there any difference?

Differences in mean success of bird identification between elementary school and university students are shown in Figure 3. Factorial analysis of variance (ANOVA) was used to examine effect of school type and treatment effects on bird identification success. Method of bird identification ($p < 0.0001$), but no type of school *per se* ($p = 0.77$) was found to be the only significant factor influencing pupils' success in bird identification. The Tukey HSD post-hoc ANOVA test that examines differences in detail, showed that the difference between pupils' success when identify birds visually (data from Picture and Song treatments) versus Song + Picture treatment (combination of acoustic and visual stimuli) were significant at $p < 0.01$ (Figure 3), whereas the latter treatment scored better. Acoustic identification of birds received lowest success in comparison with the other two treatments (both $p < 0.001$). Also, the pupils from Song + Picture treatment gained significantly higher scores than pupils which identified birds visually, independently from bird song (Picture and Song treatments), only in the elementary school sample (Tukey HSD post-hoc test, $p < 0.01$), but no similar pattern was found for the university students (visual identification vs. Song + Picture treatment, $p = 0.99$). We suggest that limited sample size for the Song + Picture treatment in the university sample ($n = 11$) could partly camouflage weak differences between visual identification versus Song + Picture treatment in university students. Gender differences, in any case, were not apparent.

DISCUSSION

Birds are animals with conspicuous habits, but also songs that cannot be overlooked. Traditional biology settings use only textbooks or additional pictures of animals ignoring their acoustic signals. As far as we know, this is the first study which investigated the importance of visual and acoustic stimuli in biology education. Previous research in pupils' abilities to identify birds used only visual stimuli leaving acoustic stimuli unexamined (e.g. Randler & Bogner, 2002; Prokop, Kubiatko, & Fančovičová, 2007a; Randler, 2009). We found out that, at least for the elementary school pupils, acoustic signals can help the pupil to identify birds more successfully than when only visual features are used. Our data supports the idea that some birds have familiar songs, such as the cuckoo, which are more noticeable than bird growth habits. These species can be more easily identified acoustically than visually. We also propose that pupils can build independent concepts of some birds following their song and growth habit. For example, when pupils looked at a picture of a blackbird, they were not very familiar with it, even though the blackbird is a common sympatric bird included in 6th grade biology textbooks, and every pupil must know that something like a blackbird exists. However, students hearing its song were often quoted:

> "*I have heard this bird usually in the early morning somewhere around my home*", or "*I know the song of this bird, but I do not know what it looks like*" etc.

Perhaps surprisingly, identification skills of elementary school pupils and biology majors did not significantly differ. Interestingly, Randler (2009) also reported similar success (about 40%) of bird identification through visual stimuli in primary children (grade 2 – 4). This supports the idea that knowledge of biology on this topic is rapidly acquired before the age of 10 (Carey, 1985; Jaakola & Slaughter, 2002) and further acquirement is somewhat slower. This phenomenon can be explained by current high school biology curricula that are not directed on pupil identification skills of either animals or plants. Instead, they are focused mainly on animal anatomy, physiology, or higher taxonomy.

Learning is obviously crucial for the way in which children acquire biological concepts (Reiss & Tunnicliffe, 1999). Perhaps surprisingly, children of all ages seem to learn more about the names and classification of animals from their homes and from direct out-of-school observations, than from school, books, or other media (Tunnicliffe & Reiss, 1999). The role of school in learning about animals should not be overlooked, but, the efficacy of the learning process should be improved. Especially the use of taxidermic bird specimens was shown to provide better educational tools than slides with regard to long-term training of identification skills in 10 – 12 year old pupils (Randler & Bogner, 2002). Learning outside school also provided a significant increase of pupil knowledge of birds, as was currently demonstrated on pupils visiting ornithological stations (Brossard, Lewenstein, & Bonney, 2005). Informal learning may therefore greatly help to develop pupil identification skills and knowledge about birds.

Educational implications

Direct educational implications emerged from the present study. First, the use of slides alone is less effective than simultaneous use of acoustic signals, at least when teaching pupils about birds. Acoustic signals may help children identify birds more easily, and the concepts about particular bird species will therefore develop more effectively. Second, more attention should be focused on pupils' abilities to identify birds. Many common, or even heavily endangered birds, are unknown to the majority of children. Third, re-evaluation of high school biology curricula in Slovakia (in terms of increasing pupils' identification skills) is necessary. Knowledge in anatomy, morphology, and/or evolution should not be acquired without pupils' basic experiences with living organisms.

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Appendix A. Pupils' success at bird identification with regard to the kind of identification method. Asterisks denote significantly higher identification success (as calculated by chi-square test) when comparing the Picture and Song + Picture treatment. Pooled data from elementary school and university sample are shown. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Bird species	Latin name	Method of identification		
		Song %	Picture %	Song + Picture %
Jay	*Garrulus glandarius*	0.91	29.09	34.09
House Martin	*Delichon urbica*	0	24.54	18.18
Black Stork	*Ciconia nigra*	0	80	70.45
Kestrel	*Falco tinnunculus*	4.55	26.36	34.09
Kingfisher	*Alcedo attis*	26.36	54.54	52.27
Great-Spotted Woodpecker	*Dendrocopos major*	72.73	92.72	93.18
Blackbird	*Turdus merula**	10.91	30	50
Swallow	*Hirundo rustica*	12.73	92.72	97.72
Sky Lark	*Alauda arvensis**	2.73	1.81	9.36
Eagle Owl	*Bubo bubo*	19.09	35.45	22.72
Green Woodpecker	*Picus viridis*	0	9.09	9.09
Chaffinch	*Fringilla coelebs*	0	11.81	9.09
Hooded Crow	*Corvus corone cornix****	80	26.36	65.9
Great Tit	*Parus major*	14.55	87.27	75
Black Redstart	*Phoenicurus ochruros*	0	0	2.27
Black Woodpecker	*Dryocopus martius***	62.73	74.54	93.18
Pheasant	*Phasianus colchicus*	29.09	100	95.45
Robin	*Erithacus rubecula*	12.73	10	11.36
Cuckoo	*Cuculus canorus****	89.09	37.27	97.72
Black-billed Magpie	*Pica pica*	11.82	20.09	31.81
Hoopoe	*Upupa epops*	I.82	20	9.09
Goldfinch	*Carduelis carduelis*	0	0.9	0
Turtle Dove	*Streptopelia turtur***	7.27	9.09	25
Black-headed Gull	*Larus ridibundus***	0.91	37.27	59.09
House Sparrow	*Passer domesticus*	8.18	70.9	63.63
Mean success	-	18.73	39.3	45.26

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Attitudes and Interests Towards Biotechnology: the Mismatch Between Students and Teachers

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Increasing the scientific literacy of Australians has become an educational priority in recent times. The 'Science State – Smart State' initiative of the Queensland Government involves an action plan for improving science education that includes a Science for Life action. A desired outcome is for an increased understanding of the natural world so that responsible decisions concerning our future wellbeing can be made in an age of science and technology. Biotechnology is a technology that is having profound impact on our lives. This paper describes how 15-16 year old students and biology teachers revealed a mismatch in both attitudes and interests towards biotechnology between the students and teachers. The findings are of interest as the teachers are writing biotechnology into their work programs in response to new syllabus documents. The teacher's areas of interest did not match those of the students, possibly resulting in a curriculum the teachers want to teach, but the students do not want to learn.

Keywords: Biotechnology, Attitude, Interest, Australia

AIMS OF BIOTECHNOLOGY EDUCATION

There is a need for science curriculum's to be relevant, modern and reflective of the needs and values of the community. It is argued that in upholding these pedagogical guidelines, there is an important place in a modern science curriculum for biotechnology education. The inclusion of biotechnology is an important topic in a modern science curriculum in that it increasingly plays a role in the daily lives of citizens. The teaching of biotechnology within a science education presents teachers with many challenges. The vast volume of information rapidly being disseminated in biotechnology leads to a number of practical problems in teaching it to science students. Teachers are faced with questions about what knowledge, and ethical issues related to biotechnology could be taught. Teachers need to address how these topics can be taught effectively. Biotechnology presents broader philosophical questions to the teacher and their students. Some aspects of biotechnology, for example, confront questions concerning the origin of life, and how life itself is defined. Arguably, biotechnology constitutes a very significant and relevant topic for inclusion in a modem science education.

The inclusion of biotechnology in the Australian science curriculum is promoted by a number of educational and scientific authorities. The Commonwealth Government has funded Biotechnology Australia and Curriculum Corporation in the development of *Biotechnology Online* (http://www.biotechnologyonline.gov.au/) which is a collection of teaching resources for biotechnology. Arguably, in respect to biotechnology, of foremost importance is public participation in this new technology. This participation cannot occur without a sound and comprehensive biotechnology education. If people are not educated in issues of science and technology, they cannot have a meaningful participation in the public debates concerning these issues. A biotechnology education requires that students, and thus future citizens, are well informed so they are able to effectively engage in public debate. In a contemporary

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science education, foundation knowledge of biotechnology principals and the related ethical issues are essential for effective engagement in public debate concerning biotechnology. The teaching of biotechnology therefore must provide for a sound understanding of its scientific basis. In addition, there needs to be opportunities for students to develop critical thinking and decision-making skills regarding the ethical use of biotechnology.

Biotechnology is regarded as a very important development for both scientific and economic progress. For this reason, governments and private sector interests strongly support the concept of biotechnology education. The national science framework also recognizes the need for science students to be made aware of biotechnology as an important topic for the Australian Science Curriculum. Curriculum planners and educators are therefore encouraged to incorporate biotechnology into science curriculum. Suggested biotechnology topics that could be taught in a general biology curriculum include: bioethics in biotechnology, biotechnology in agriculture, medicine, environmental science and industry, defining biotechnology, molecular biology of cancer, organismal biochemistry, microbiology, genetic engineering, human genetics and genomic library, molecular biology as a discipline, and DNA fingerprinting.

However, teaching all of these topics is not practical. Planning can assist in deciding which topics could be included in the teaching of biotechnology. A mandate already exists in the Queensland biological science curriculum to allow teachers in Queensland to use their professional judgement in making decisions on what materials are taught in view of their specific student circumstances (Queensland Studies Authority, 2004). To date, no formal planning has occurred in relation to determining the particular attitudes and interests of the key stakeholders – the students and teachers. This study aims to determine the baseline information in relation to biotechnology attitudes and interests of Queensland students and their teachers.

Biotechnology in the Curriculum

Literature that supports the view that biotechnology should be included in a secondary school science education includes Chen and Raffan (1999) who investigated the knowledge and attitudes of Taiwanese and United Kingdom students aged 17-18 regarding biotechnology. The results from the study indicated a limited understanding of biotechnology by these students. However the study noted some differences in student understandings. For example, students in Taiwan did not demonstrate the diversity of definitions and examples that the UK students did. Chen and Raffan (1999) suggest this may be accounted for by the different curriculum approaches both countries have. The UK curriculum allowed for a number of learning opportunities where students had access to biotechnology resources as textbooks, media, contact from scientists and general studies materials; as well as opportunities to discuss the ethical issues associated with biotechnology. This was in contrast to the Taiwanese curriculum, which was more demanding in the sense that students studied more subjects and were more examination orientated in their learning context.

Chen and Raffan (1999) concluded that a good biotechnology education has implications for students and teachers. A biotechnology education is not intended to promote biotechnology or produce students with positive attitudes to it. A good biotechnology educational outcome gives the students current and accurate knowledge, and the opportunities to form their own views, based on their understandings of risks, benefits and disadvantages of modern biotechnology. For teachers, thorough preparation of subject material and opportunities to give students a chance to develop informed views on controversial biotechnological topics are important pedagogical goals. Overall, Chen and Raffan (1999) suggested that the end product of biotechnology education is to assist students to develop independent thinking skills and be better prepared to think about and deal with controversial topics encountered in their future lives.

Dawson and Taylor (2000) support biotechnology education, stating that "If our students are to become well-informed decision makers then they need to be aware of the practical applications of current developments in biotechnology, and appreciate the social and bioethical implications of this relatively new and controversial science (p. 184). With the increase in pace of biotechnology developments since the early 1990's, it is important to educate secondary school students about biotechnology. Schibeci (2000) suggests that as biotechnology is a rapidly developing technology with much health, economic and environmental benefits to Australia, the teaching of biotechnology and its impact on the community is of importance. He advocates that rather than devote a special unit on ethics or the social implications of science and technology, these topics can be taught with the use of a variety of techniques such as laboratory exercises and case studies. Regardless of the methods employed in their teaching, Schibeci further recognizes that the teaching of biotechnology is important both in terms of its science as well as providing a vehicle to examine ethical issues associated with its use.

Crucial to the development of biotechnology education in secondary classrooms are the teachers themselves. Whilst Australia has syllabus mandates and commonwealth funded web sites to develop biotechnology skills in the classroom, there seems to be reluctance from the teachers to present biotechnology lessons. Steele and Aubusson (2004) interview a number of teachers to determine why they were not presenting biotechnology in their biology classrooms. Although the teachers appeared to have a sound understanding of the content, they felt biotechnology was too difficult for the students, and this would disadvantage the students in the university entrance examinations. Another problem according to the teachers is the lack of opportunity for practical work in the classroom.

Biotechnology Attitudes and Interests

The need for attitudinal research in biotechnology is paramount. Researchers have shown that becoming a scientific literate person is not a high priority for many students (Atwater, Wiggins, & Gardner, 1995; Zacharia, 2003). A particular need identified by Zacharia is to investigate the extent the learning experience enhances the students' attitude towards science learning. Zacharia found that a teacher's attitude toward the subject matter and its effective presentation was as significant as the students' perspectives in determining the success of the teaching/learning experience. Fishbein and Ajzen (1975) laid the foundations for the study of attitudes. They argued that 'attitudes' are a function of the individual's beliefs and an evaluative response associated with the belief. Therefore beliefs affect attitudes, and attitudes then affect intentions. This function between attitude and intention is important when considering the impact a teacher has on the curriculum and learning environment.

Student and teacher attitudes have been investigated in various, but separate studies over recent decades. Haladyna and Shaughnessy (1982) posited students' attitudes are determined by the teacher, the student and the learning environment. Simpson and Oliver (1990) later found the preparation of the teacher, the nature of the hands-on activities, and the student involvement in the learning are important variables in student attitude. Hewson, Kerby, and Cook (1995) argued that teachers' conceptions and attitudes have a strong influence on science teaching and learning. Therefore questions about what impact teachers' attitudes have on classroom practice are of great importance. Zacharia (2003) argues the efforts of the science education community should focus on research issues related to the understanding and development of teacher attitudes because of their strong link to classroom action.

Dawson and Schibeci (2003), and Gunter, Kinderlerer and Beyleveld (1998) both conducted surveys of secondary school students attitudes about what are acceptable biotechnology processes. Most support was found for the use of micro-organisms for specific purposes such as beer manufacture. Less support was found for the genetic modification of plants for food, and even less for the genetic modification of animals and humans. In another study Dawson and Schibeci (2003) investigated biotechnology understanding in 15-16 year old students. They found that after 10 years of compulsory schooling in science, the majority of students did not understand the processes of biotechnology. The few studies that have investigated the relationships between biotechnology understandings and attitudes have been inconclusive in their findings (see Olsher & Dreyful, 1999; Dawson, 2003).

There is support for the notion that scientific interest affects science achievement (Benbow and Minor, 1986; Dhindsa and Chung, 2003; Freedman, 1997; Kahle & Meese, 1994; Salta & Tzougraki, 2004; Simpson, Koballa, Oliver, & Crawley, 1994; Weinburgh, 1995). Whilst these studies relate to science education none relate directly to the biotechnology subfield. The emphases of these studies relate to gender and gifted and talented students, but the findings are not consistent. One reason postulated by Chambers and Andre (1997) for inconsistent results in interest research is that the interest instruments used may not be valid instruments. By considering Ajzen and Fishbein (1980) theory of reasoned action, it is possible that inconsistent results may arise from the use of a domain-general instrument rather than a topic-specific instrument. It can be argued that domain-general attitude and interest measures should not be expected to produce quality results in topic-specific studies. Topic- specific attitude and interest instruments are necessary to explore attitude and interest relationships. Consistent with this notion, the present study examines biotechnology attitudes and interests through a purposely constructed topic-specific instrument.

Importance of the study

Research in this domain is needed for a number of reasons. There is a scarcity of research into biotechnology education. A second reason is that teachers' attitudes have an effect on science classroom practice in general, but the extent is not known in relation to biotechnology. A third reason is to investigate the links between biotechnology attitudes and interests of both students and teachers – a yet untapped area. As far as the author is aware, there is no published research which compares the biotechnology knowledge, attitudes and interests of students with those of their teachers. Finally, biotechnology is perceived as being risky for some people (Slovic, (1987), so the question of whether there is a correlation between attitude and knowledge remains unclear and needs exploring. The aim of this study is to provide baseline data on student and teacher knowledge, attitudes and interests to biotechnological topics and processes. Whilst the larger study explores knowledge, attitude and interests across the areas of environmental biotechnology, agricultural biotechnology, genetically modified foods, human uses of biotechnology, and science lesson topics, this present paper focuses particularly on the areas of attitudes 'towards' biotechnology, and interest in science lesson topics.

Questionnaire Methodology

A series of questionnaires (Biotechnology Education Learning/Biotechnology Education Teaching Survey - BELBETS) were used with 508 15-16 year old students of senior biological science and their 35 teachers from eight secondary schools scattered throughout Queensland, Australia. All Year 11 biology students and their teachers present on the days the surveys were administered completed the survey. Eight student surveys were discarded. Of these, six students did not complete the survey in any meaningful fashion (they answered 'Strongly Agree' to all questions or made no attempt to answer any question at all); whilst the remaining two students left major sections of each scale blank.

The administration of the BELBETS is continuing in Queensland schools, however this paper reports the initial findings of the 500 students and their 35 teachers. It is acknowledged that the teacher sample is small, and therefore statistically unstable. The questionnaires use a five point Lickert scale (Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree) with items adapted from Dawson and Schibeci (2003) and Chen and Raffan (1999) and Biotechnology Online (2001). Additional items were created based upon general readings and Internet coverage. A full copy of the BELBETS is available from the author. The student and teacher surveys vary slightly. The statements differ in that a student may read a question written in the following way: *I would be interested in learning about* ….. Whereas, a teacher would read the same question, but in two parts as: *I would be interested in teaching about* ….. and *I think I have the knowledge and skills to teach about* …..

The results of the questionnaires were coded, and analysed using the Statistical Package for the Social Sciences (SPSS). Additional interviews were held with 60 students and three teachers (from three geographically different schools) who had responded to the survey. The interviews were to seek information on the wording and readability of the items, as well as to establish reasons for which the students and teachers gave their particular responses. All students were interviewed by the researcher or a research assistant. Two of the three teachers had to be interviewed via telephone. The full questionnaire revealed five scales: two of the scales relate to biotechnology practices: Towards Biotechnology; and About Biotechnology. Another two scales relate to biotechnology risk: Risk to Humans; and Risk to Environment. The remaining scale relates to the classroom use of biotechnology: Science Lesson Topics. It is the first and last scales that are reported in this paper.

Table 1 report, in accordance to Anastasi (1996), the statistical data relevant to the internal consistency reliability (Cronbach alpha coefficient) and discriminant validity (factor loadings and interscale correlations).

Table 1. Statistical details pertaining to the internal consistency reliability of the 'attitude' items

Scale	Respondent	No of items	Cronbach Alpha	Factor Loadings	Interscale correlations
Towards Biotechnology	Student	7	.73	.65-.88	.22-.35
	Teacher		.84	.71-.91	.33-.41
About Biotechnology	Student	3	.69	.54-.76	.18-.32
	Teacher		.72	.69-.81	.21-.46
Risk to Humans	Student	9	.77	.64-.80	.33-.67
	Teacher		.79	.49-.75	.29-.45
Risk to Environment	Student	5	.81	.74-.91	.38-.59
	Teacher		.91	.81-.95	.31-.51
Science Lesson Topics	Student	4	.88	.61-.79	.21-.51
	Teacher		.90	.71-.82	.26-.57

Table 2. Statistical details pertaining to the Pearson Chi-square for the 'attitude' items

Scale	BELBETS Scale Item Number	Pearson Chi-square
Towards Biotechnology	4, 5, 7, 8, 10, 11, 13	7.432**
About Biotechnology	1, 2, 3	3.448
Risk to Humans	12, 16, 17, 18, 21, 22, 23, 24	6.015*
Risk to Environment	9, 14, 15, 19, 25	4.058
Science lessons	57, 58, 59, 60	111.055***

Note: The asterisks indicate if the Chi-square statistic was statistically significant between the student and teacher (*p < .05; ** p < .025; *** p < .005).

The alpha reliability of the scales ranged from .69 to .91 indicating strong internal consistency within each scale. Omitting items in some scales would have increased scale internal consistency, however these items were preserved to ensure the scale addressed several aspects of the same dimension. As an example, "*About technology"* scale Item 3 (I think that genetic engineering is important because it helps to reduce hereditary disease) could have been omitted to increase the internal consistency of the scale but was retained because of the importance of hereditary concepts in biotechnology. Interscale correlations were generally low, indicating that each scale measured an individual property. Factor loadings for individual items are generally above .5, indicating acceptable association between items scales. In all cases acceptable divergent validity is shown as the Cronbach alpha's are greater than the interscale correlations. Table 2 reports the Pearson Chi-square statistical data. These results indicate that corresponding responses between the students (BEL) and the teachers (BETS) were different enough so that generalisations can be made.

To facilitate comparisons between the student and teacher responses a mean score was calculated for each question using responses of the whole group by scoring 'Strongly Agree' responses as 1.0, 'Agree' as 0.5, 'Neutral' as 0, 'Disagree' as -0.5 and 'Strongly Disagree' as -1.0. As the mean approaches a value of 1 it indicates affirmation of the statement, and as the whole group mean approaches -1 it indicates rejection of the statement. By plotting the 'Whole Group Mean' in a horizontal bar graph, a visual impression of the relationships between student and teacher responses is possible.

RESULTS

The results of the survey are presented in both tabular and graphic form and presented in two sections: (a) Attitudes towards biotechnology; and (b) Science lesson topics of interest.

Attitudes 'towards' biotechnology

Seven items in the BELBETS questionnaire probed the student and teacher attitudes 'towards' biotechnology. Items within this scale relate to the acceptance of gene modification in plants. The responses from the students and teachers, as well as the Whole Group Mean scores are provided in Table 3 (figures in parentheses are teacher responses).

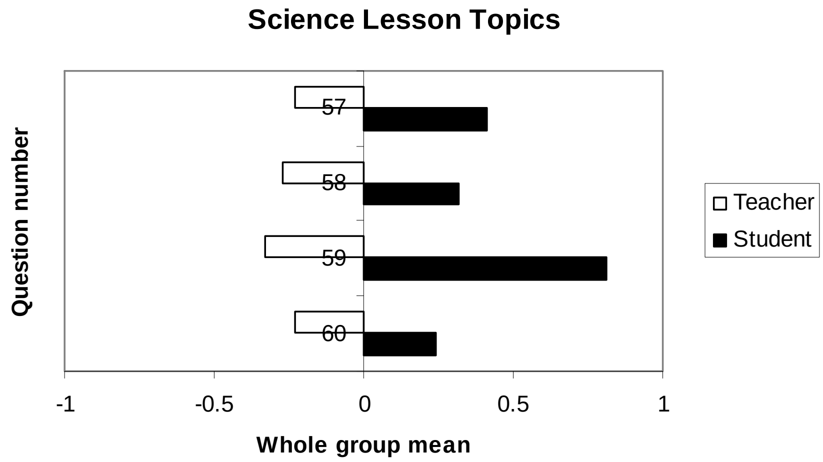
Careful scrutiny of Table 3 will reveal that student and teacher attitudes are similar on a number of items (Items 7, 10 and 13), but vastly different on others (Items 4, 5, 8 and 13). Figure 1 indicates this at a glance.

From Figure 1 it is obvious that there is a student teacher mismatch in relation to attitudes concerning the genetic modification (GM) of food, animals and humans. Students tend to reject the general use of GM, yet teachers tend to accept it (Item 4). When the statements are made more specific to be only the GM of micro-organisms and plants – to the exclusion of animals and humans, the students change their attitudes towards acceptance. Another mismatch occurs in Item 11 in relation to GM micro-organisms for treating human waste. The majority of students (70%) accept this form of biotechnology, whilst 47% of teachers reject it.

When probed in interviews, a number of teachers claimed to look at the bigger picture of biotechnology, as Mr H (School 2) described:

Well, it is general isn't it? Modifying anything is to our benefit I think. It doesn't matter what they [the scientists] modify, people benefit … or they wouldn't be able to do it.

Another teacher, Miss T (School 5), elaborated on a fear commonly held by the teacher's in relation to Item 11:



Note: As the mean approaches a value of 1 it indicates affirmation of the statement, and as the mean approaches -1 it indicates rejection of the statement.

Figure 2. Whole group mean scores for student and teacher interests.

Table 3. Student and teacher: Attitudes 'towards' biotechnology.

Item	Statement					
4	*I accept that the genetic modification of food, animals and human is a good thing.*					
		SA	A	N	D	SD
	n	0 (0)	28 (3)	86 (3)	156 (6)	230 (3)
	%	0 (0)	6 (20)	17 (20)	31 (40)	46 (20)
					Whole group mean adjusted	-0.59 (0.30)
5	*I think it is acceptable to modify the genes of micro-organisms and plants.*					
		SA	A	N	D	SD
	n	198 (2)	256 (7)	30 (1)	16 (3)	0 (2)
	%	40 (13)	51 (47)	6 (7)	3 (20)	0 (13)
					Whole group mean adjusted	0.64 (0.13)
7	*Altering the genes of plants so that they will grow better in salty soils is acceptable.*					
		SA	A	N	D	SD
	n	195 (5)	250 (9)	30 (0)	25 (1)	0 (0)
	%	39 (35)	50 (60)	6 (0)	25 (5)	0 (0)
					Whole group mean adjusted	0.62 (0.60)
8	*I think that adding genes to plants to increase their nutritional value is acceptable.*					
		SA	A	N	D	SD
	n	59 (4)	268 (1)	69 (6)	82 (3)	22 (1)
	%	12 (27)	54 (13)	14 (40)	16 (20)	4 (7)
					Whole group mean adjusted	0.35 (0.13)
10	*Altering genes in tomatoes to make them ripen more slowly and have a longer shelf life is a good use of biotechnology.*					
		SA	A	N	D	SD
	n	98 (1)	168 (7)	95 (3)	70 (1)	69 (3)
	%	20 (7)	34 (47)	19 (20)	14 (7)	14 (20)
					Whole group mean adjusted	0.16 (0.07)
11	*Using genetically engineered micro-organisms to break down human sewerage is a good thing.*					
		SA	A	N	D	SD
	n	100 (0)	250 (2)	50 (6)	70 (4)	30 (3)
	%	20 (0)	50 (13)	1 (40)	14 (27)	6 (20)
					Whole group mean adjusted	0.32 (-0.26)
13	*Altering genes in fruit to improve taste is a good idea.*					
		SA	A	N	D	SD
	n	120 (5)	150 (5)	80(1)	75 (2)	75 (2)
	%	24 (33)	30 (33)	16 (7)	15 (13)	15 (13)
					Whole group mean adjusted	0.17 (0.30)

Note: Figures show the number and percentage of valid student responses for each Likert category. Figures in parentheses are the number and percentage of valid teacher responses for each Likert category.

I don't think it is good to breed super sewage bugs. I think there was a movie a while back where a super bug escaped or something. We already have super streptococcus bugs invading our hospitals. Anyway, imagine if a super bug was to attack sewage, eventually it may mutate or become airborne or something. It would then be present everywhere there is dung .. on our lawns from dogs, on surfaces from poor human hygene .. yuck .. anyway, so this super bug mutates from dung to skin and well …. Yea this is hypothetical but possible.

Students, on the other hand held a different view:

Too right it is a good idea. We could get rid of a whole lot more shit … oh sorry … pooh! Sewage farms could use less water, and like … yea maybe not smell as much. So it would be good (Matt, School 1, Teacher 3).

The existence of these mismatches hold great potential for the biology classroom e.g. explorations of the nature of superbugs, decomposition by miocro-organisms, and the possibility of classroom debate –

student versus teacher. For this to occur, the teacher needs to be familiar with their class' attitudes, but first and foremost, the teacher must be interested in presenting lessons on such topics!

Science lesson topics of interest

Four items in the BELBETS questionnaire investigated the student and teacher interests in four biotechnology topics that could be explored in biology lessons. The responses from the students and teachers, as well as the Whole Group Mean scores are provided in Table 4 (figures in parentheses are teacher responses). Figure 2 provides a simple comparison between student and teacher lesson topic interests.

The majority of Year 11 students (70%) declared an interest in having bioethical topics presented in the classroom:

Bioethics, yea, they are everywhere, like on the news, TV shows and in the papers. I saw a cool episode once on 'House' where the team had to decide to do an emergency op [operation] not in the theatre 'cause another person also needed the operating theatre. Doctors have to make decisions like that all the time so we should be able to do debates and stuff like that too….. Lessons would be more interesting if they were gory and real. (Simon, School 6, Teacher 4)

As one teacher indicated, "I don't want to cover such things. There is a possibility that someone may be offended by another's views, discussions could become a debate, and it is the English teacher's job to do debates, not mine." (Mr H, School 2)

Similar patterns can be found in the responses to Question 58 relating to prenatal testing. The majority of teachers do not want to teach prenatal testing. As Mrs P (School 3) said:

I don't like the idea of a woman knowing her unborn child has a problem, and then her choosing a termination. What if the father didn't want to terminate? We then have a problem. No, ethically I don't like it. I don't think the students should have to explore such things. It isn't really relevant to them at the moment. Besides, it isn't in our text book I don't think.

An examination of the Whole Group Mean data in Figure 1 indicates that the students and teachers surveyed have very different ideas of what topics are of interest for inclusion into biology lessons. This opposition of interests is responsible for at least 1 student reconsidering his enrolment in the subject:

This subject is boring. If I had known we would not be doing cool stuff like CSI, I wouldn't have done biology. I am going to drop it next term and do something else. All the teacher does is text book stuff like study questions and stuff. We do an experiment once in a while if we are good, but sometimes they don't

Table 4. Student and teacher: Science lesson topics of interest.

Item	Statement				
57 (77) *Bioethics education should be discussed in science lessons.*					
	SA	A	N	D	SD
n	169 (1)	181 (2)	75 (5)	40 (3)	35 (4)
%	34 (7)	36 (13)	15 (33)	8 (20)	7 (27)
				Whole group mean adjusted	0.41 (-0.23)
58 (78) *Prenatal testing and the issues associated with it should be discussed in science lessons.*					
	SA	A	N	D	SD
n	120 (0)	130 (1)	200 (8)	45 (3)	5 (3)
%	24 (0)	26 (7)	40 (53)	9 (20)	1 (20)
				Whole group mean adjusted	0.32 (-0.27)
59 (79) *Birth control and the issues associated with it should be discussed in science lessons.*					
	SA	A	N	D	SD
n	308 (0)	192 (0)	0 (7)	0 (6)	0 (2)
%	62 (0)	38 (0)	0 (47)	0 (40)	0 (13)
				Whole group mean adjusted	0.81 (-0.33)
60 (80) *Human cloning and the issues associated with it should be discussed in science lessons.*					
	SA	A	N	D	SD
n	98 (1)	186 (1)	121 (5)	50 (6)	45 (2)
%	20 (7)	37 (7)	24 (34)	10 (40)	9 (13)
				Whole group mean adjusted	0.24 (-0.23)

Note: Figures show the number and percentage of valid student responses for each Likert category. Numbers in parentheses are the number and percentage of valid teacher responses for each Likert category.

work out like they should. (Paul, School 1, Teacher 3)

It is well known that students are not selecting the sciences in post compulsory schooling, and this has had a flow-on effect into tertiary studies. There have been a number of explanations posited for this demise in science interests; however, very few if any have explored the link between teacher and student interests. It is obvious from these four questionnaire statements, that the students and teachers have opposing interests. The teachers are not interested in providing lessons on the topics students are interested in learning about. In Queensland this is problematic, as the teachers design the curriculum for their particular students. If the small number of teachers surveyed and interviewed is representative of Queensland or Australian biology teachers, it seems teachers do not want to get involved in controversial issues, and they do not want to present topics not found in the text book. Students, on the other hand want to explore ethical concerns. They see shows on the television, consider this material to be 'real' (irrespective of whether it is or not), and desire to do hands-on practical work. One student enrolled in biology in a post compulsory classroom, but found his interests not being met. He planned to withdraw from the study of biology at the first opportunity. The student did not know what subject he would enrol in after biology, except that he knew "it wouldn't be a science subject" (Paul, School 1, Teacher 3). It is unknown how widespread this 'lack of interest' causing departure from a science subject is.

DISCUSSION AND CONCLUSION

In Australia, it is common for educational authorities to impose syllabus documents and standards, for teachers to react and possibly trial the documents, and then for teachers to create work programs and implement them within their schools. It is very rare for any of these documents to be written following consultation with students. Yet the data from the BELBETS questionnaire indicates it may be beneficial to determine the attitudes and interests of the students, as in some cases, there will be disparities with the attitudes and interests of the teacher. The attitudes of the teacher and students may differ, providing a rich discussion or debating base for the classroom. Where attitudes, tend to match, it is highly unlikely the match will be unanimous, so debate and discussion is still possible. The BELBETS has also shown that students have very clear ideas of what they are interested in exploring in biology classes. Where these interests are not being met, it is possible the student will withdraw from the study of biology. This study found that students have very positive attitudes towards studying biotechnology issues, especially where there is personal relevance. Unfortunately, the study also showed that the teachers, who decide upon the curriculum, are not interesting teaching such topics.

It is hoped that the findings from this study will lead to further investigations into biotechnology education. We need more studies that investigate biotechnology education in relation to teacher intention in the classroom. Research into student attrition from the sciences is also needed to determine if the mismatch between student and teacher interests is a contributing factor.

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A Critical Discussion of The Efficacy of Using Visual Learning Aids From The Internet To Promote Understanding, Illustrated With Examples Explaining The Daniell Voltaic Cell

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This paper discusses what chemistry students might see while working with animations found on the Internet and how these electronic illustrations can potentially interact to reinforce rather than resolve misconceptions about chemical principles that a student may possess. The Daniell voltaic cell serves as an example to illustrate the ways in which visual aids can be interpreted differently by different people. Some illustrations seem to represent concepts which have repeatedly been discussed on the base of science education research evidence as typical student misconceptions about chemical concepts. These visual aids seem to embody the actual misconceptions of chemical principles rather than explaining the scientifically accepted chemical concepts behind them. This paper discusses whether such computer simulations are potentially helpful for better understanding, or whether they actually increase the risk of strengthening students' incorrect interpretations or false ideas about chemical concepts. Implications for structuring and using animations are discussed.

Keywords: Chemistry Education, Multimedia Learning, Animations, Misconceptions

INTRODUCTION

"WYSIWYG - What you see is what you get" was an innovation in information technology some 15 years ago. Until this shift towards WYSIWYG-technology occurred, cognitive tools like text editors had not been able to accurately depict edited materials on the computer monitor in their real layout while simultaneously working with and altering them. Frequently, this led to various surprises when printing a hardcopy of the material. Today, it is no longer a problem to display correct fonts, page layouts or picture elements on the screen while simultaneously processing documents and files. Moreover, with the modern tools existing today, there is almost no difficulty in creating

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pictures, simulations, and visual aids in any form and context we like. Modern computer games beautifully demonstrate the current, cutting-edge breakthroughs in developing illustrations and animated programs.

On a certain level animation technology no longer demands highly specialized programmers. Applications like Macromedia Flash have become easy to use and many curriculum planners and teachers are now able to create animated aids using these tools. This has led to a large increase in the number of animated visual aids on the Internet for a variety of science topics. But the question remains whether all of these animated illustrations are truly useful in supporting learning. Does any given illustration from the Internet provide us with what we really want or need to have? Do illustrations support learning processes simply by showing chemical concepts in an electronically animated format?

The question of whether we get what we see or, perhaps more importantly, what students perceive when watching animations, must be asked from a different point of view. This is because focusing on the use of animated illustrations in education is different than discussing computer games played merely for entertainment. We know from constructivist theories of learning (e. g., Bodner, 1986) that visual aids are not captured in learners' heads without being filtered and interpreted using the framework of the viewer's preconceptions. We use illustrations in science education in the hope that they will promote a deeper comprehension and understanding of scientific principles. Such visual aids are used to challenge alternate or incorrect beliefs about scientific principles, and to provoke a shift towards scientifically acceptable concepts. In chemistry, teaching with this goal in mind is especially linked to the understanding of the submicroscopic level of matter, which is invisible to the human eye and therefore largely dependent on human imagination. It is in trying to link what we actually observe to what happens at the submicroscopic level that causes the main difficulties in learning chemistry (Johnstone, 1991).

We will discuss differences in what learners can conclude by viewing illustrations found in the Internet by using two illustrations of the Daniell cell as examples. A look at both the potential perspectives of teachers and those of learners viewing the same images may help to sensitize us more deeply to the possible interpretations of computer-animated illustrations.

Learning by visualisation

Today learning as a whole and so learning with visualisations is generally referred to a constructivist understanding of learning as described, e. g., by Bodner (1986). The central message is that students get information, e. g. via a computer screen, and will construct from this information together with the knowledge they have new ideas and concepts. In his article on contructivist learning, Storck (1995) points out three essentials:

Concepts, ideas and knowledge that the students bring with them into the classroom have to be taken into account when evaluating, planning and structuring learning processes.

Provoking cognitive conflicts and their solutions is of high potential value for facilitating a change in student preconceptions into valid scientific concepts.

It is not necessary that alternative ideas about chemical principles will be replaced by scientific "truths" in all cases. There are situations where it seems to the student do be of more value to retain more naïve ideas or beliefs about scientific processes or theories. One example may illustrate this. In our everyday life, we regularly speak about the consumption of energy. It is clear that we have to support an electronic device by electricity, or a car by gasoline as a source of energy. The correct idea of a change from one form of energy into another under recognition of the principle of Conservation of Energy is not necessary here because we are thinking within this context exclusively on those forms of energy that can be used in our interest in that moment, and maybe on the costs for supplying us with "usable" energy.

Constructivist learning has been one of the leading forces for intensive empirical research into students' alternate beliefs about chemistry and also into their learning problems. Evidence has been gained in many different fields (e. g., Garnett, Garnett and Hackling, 1995), for example, electrochemistry-respective reviews were given by Garnett and Treagust (1992 a) and de Jong and Treagust (2002). Many of these studies focused on the details of understanding electrochemical cells. For a deeper understanding of this field, additional relevant information also can be obtained from more basic research on the particulate nature of matter or on the theories for understanding electricity (e. g., de Jong and Treagust, 2002).

Constructivist learning seeks to explicitly pinpoint alternate ideas about chemistry and to create learning environments where these alternate beliefs can be discussed and replaced with less naïve and scientific reliable concepts. This can be achieved by provoking a cognitive conflict and then using this conflict to promote a conceptual change (Posner, Strike, Hewson and Gertzog, 1982), e. g. where the naïve ideas can be falsified by the use of experiments. An example may illustrate this. Teachers frequently report that ions within an electrochemical cell are thought by many students to come "out of" the electrode. They then disappear after being uncharged at the electrode. In the students' minds this is not always connected with a gain or loss in the mass of the two oppositely-charged electrodes. The chemical principles of Conservation of Mass and Conservation of Atoms are not correctly applied. Students often think that the electrodes in a voltaic cell always remain unchanged during the whole process, just like the external electric circuit does. We will return to this misconception later in the discussion of different visual aids. This misconception can easily be disproved scientifically if, for example, a Daniell cell is set up and connected to an electronic device for a few hours. Both electrodes can be weighed and the loss in mass of the zinc anode and the increase in mass of the copper cathode can be measured and compared with the starting values. This experiment can be used to provoke a cognitive conflict in those students who neglect the change in mass occurring in the electrodes. Additionally, such experiments show the hands-on, experimental nature of science. A hypothesis is proposed and then proven or disproven through experimentation, the same path that Lavoisier, Boyle, or Berzelius were forced to follow in their quest for knowledge of the physical world.

Unfortunately, this scenario is limited to the phenomenological level. In most examples focusing on concepts and alternate ideas of the submicroscopic world, a similar approach is not available and this is why chemistry is so difficult to learn (Johnstone, 1991). In chemistry, we often use models to help us better understand phenomena at the submicroscopic level. With improvements in computer technology, it is now common to use computer-generated animations and simulations of the submicroscopic world. Such computer-animated illustrations provide considerable advantages over static images because they allow us to visually demonstrate the dynamic nature of the submicroscopic world.

According to Mayer (2003), students can learn more profoundly from a multimedia explanation presented in both words and pictures than in words alone ("the multimedia effect"). This effect is explained by the dual coding theory of Pavio (1986) that states that visual and verbal information in the brain are processed differently and along distinct channels while the learner creates separate representations in each channel. These different codes can interact and promote succesful learning. But, this promising process is not self evident. Schnotz and Bannert (2003) discuss the fact that pictures in multimedia learning processes are not necessarily of benefit to learning in every case. Pictures can only be understood by semantic processes. Also, pictorial information is always related to the pre-knowledge of the learner. Learning effectiveness is highly dependent on students' preconceptions. Therefore, if effective learning should take place illustrations and visual aids need to be structured to take account of the learner's pre-knowledge of a given topic. This means:

If the learner's preconceptions are scientifically reliable, illustrations should confirm and foster them.
If the learner's preconceptions of a topic are scientifically unreliable, illustrations should induce a cognitive conflict which leads to overcoming the formerly-held ideas.

In both cases it is necessary to use illustrations that are scientifically reliable and that do not demonstrate or call upon incorrect or conflicting explanations. Generally, we would think that this could always be taken for granted, but even static illustrations in school textbooks do not always meet these criteria (e. g., Eilks, 2003).

The Daniell voltaic cell as example

The Daniell cell is one of the most familiar and easy-to-use voltaic cells and is therefore the chosen example for voltaic cells in many science curricula. Nevertheless, the following discussion is just an exemplary case. Similar examples could be found for a range of other science topics.

Because the Daniell cell is an often-discussed topic in chemical education, many visual aids are available on the Internet. **Appendix** 1 lists a number of such resources for the Daniell cell from different countries. One of the examples from a German website (Figure 1) for secondary and tertiary education will be used as our first example to show the problems in "seeing" animations which do not "really" animate the science concept which is commonly accepted within the scientific community. Some of the other animations in Appendix 1 are quite better models to explain Daniell's voltaic cell in terms of our commonly accepted scientific view, while others are questionable in a similar way.

What do we see when we look at the five diagrams in figure 1? The figure illustrates steps in the animation, and the formation of zinc ions from the zinc electrode can be recognized. The external electrical circuit is completed by a salt bridge. Zinc ions are solvated by the aqueous solution around the anode. Connected to this process, two electrons are set free. The external electrical circuit conducts these electrons toward the copper electrode. The electrons become available for reducing metal ions at the copper electrode. Copper ions in the solution move toward the copper cathode and accept the electrons. Copper atoms are formed and deposited on the copper electrode. Overall, we see a flow of electric current, which would be able to power a small engine.

But is this really what we see? Most of the things described above cannot, in fact, be seen within the animation. Most of the steps involved are interpretations stemming from the pre-knowledge we possess: They represent rather our teacher's expert knowledge of voltaic cells.

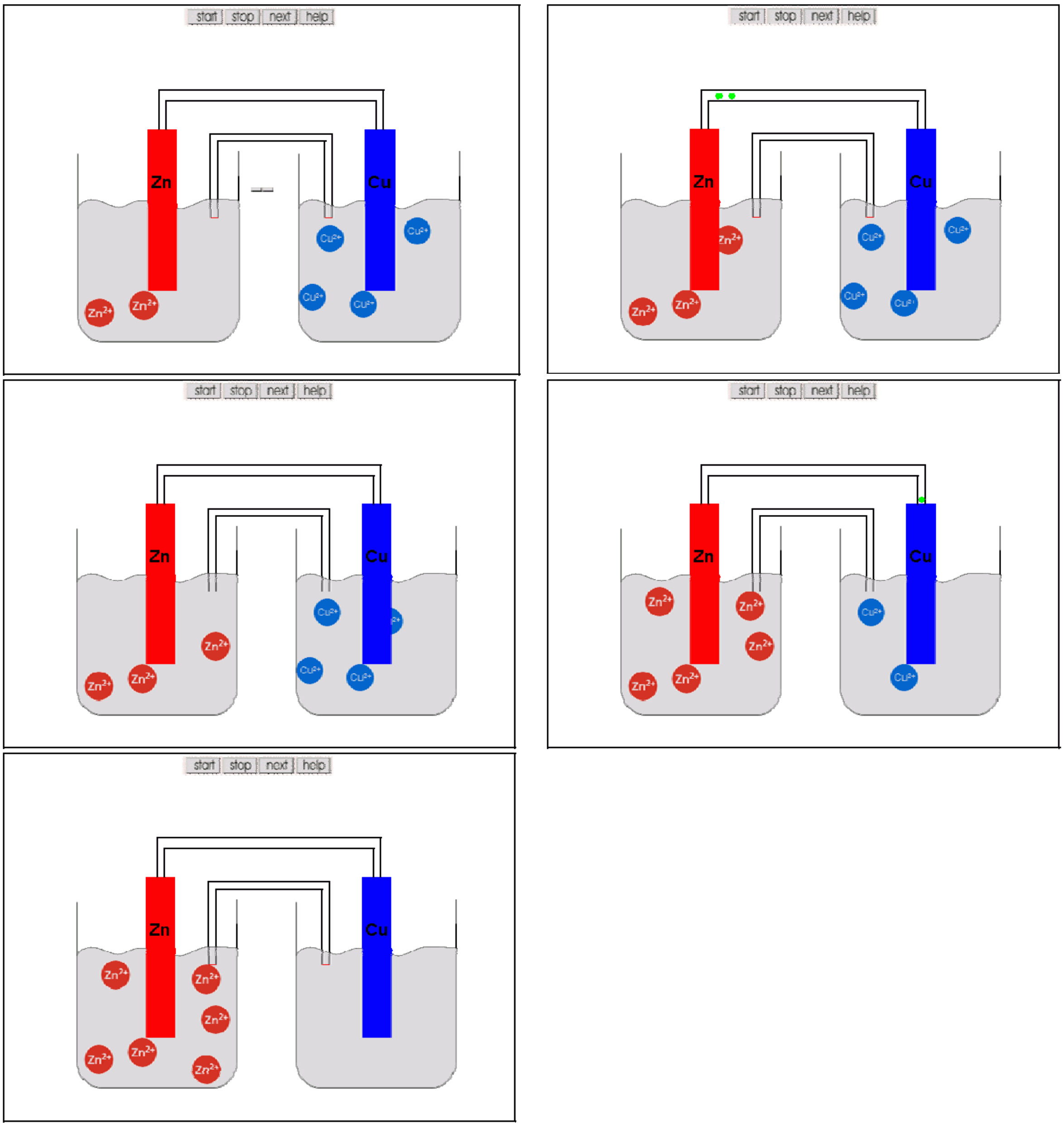

Figure 1: An animation on the Daniell cell from the internet (ChemgaPedia, 2008)

What then do we really see? What we see is a zinc electrode. This electrode is represented as a continuum: it does not consist of atoms. If we take into consideration the fact that zinc atoms are larger than the corresponding zinc ions, it is impossible to believe that the zinc electrode consists of zinc atoms. The electrode is thinner than any of the zinc atoms could possibly be. Starting at the zinc electrode, zinc ions move into the solution. The ions either come out of the electrode or from behind it. The ions move into a continuous "grey zone", which is not involved in the whole process. During the entire reaction there are no changes in the zinc electrode's mass or size. It is not reduced (see above). Accompanying the appearance of the zinc ions,

Table 1. Selected results from empirical research about scientifically unreliable concepts from students, with relevance for understanding electrochemical cells

- The particulate nature of matter often is misinterpreted as an understanding of particles within a continuum (Novick and Nussbaum, 1978). Sometimes an understanding of the particulate nature of matter within a system is limited to single substances. These are those substances which are in the focus of the discussion (Ahtee and Varjola, 1998). These kinds of mixed interpretations sometimes are kept during the whole schooling time (Nakleh, 1992).
- Macroscopic changes are sometimes referred to as similar changes in the particles (Lee, Eichinger, Anderson, Berkheimer and Blakeslee, 1993). This can be true even for mass changes. If matter is no longer visible it seems to disappear along with its particles (Stavy, 1990). It is not only important to keep the principle of mass conservation in mind, but also to retain the principle of atom conservation (Gomez, Pozo and Sanz, 1995).
- Current flow often is over-generalized as a flow of electrons. This is a reliable idea for portraying conductivity in metals. But sometimes an understanding of electrolytic conductivity as a flow of free electrons through the electrolyte has been observed. The concept of the movement of ions is not applied (Grosslight, Unger, Jay and Smith, 1991; Garnett and Treagust, 1992b; Ogude and Bradley, 1994, 1996).
- Current flow is not necessarily connected to the concept of a circuit. There are misinterpretations in understanding electric current as something flowing from the source to the device (de Posada, 1997). The necessity of a salt bridge therefore is not understood. The external and internal electric circuits are not seen as one entity (Burger, 2000).
- Students sometimes adhere to a concept where electrolytes do not contain ions, but instead salts. Ions are formed at the moment voltage is put across the solution or an electrolytic process started (Ogude and Bradley, 1994, 1996; Butts and Smith, 1987)

Table 2. Some ideas from empirical research and taken into account, some compromises made in figure 2

Considered ideas	Compromises
Electrodes are composed of atoms of zinc or copper, respectively. During the reaction, zinc atoms are changed into ions. The zinc ions are dissolved. Solvated copper ions are changed into copper atoms and form new copper at the copper electrode.	The particles of the solvent are not shown. The level of the solution is sketched, but a grey or colourful sketch of a continuum is not shown. Additional information is available as a pop-up window, where a picture is available showing all particles within both half-cells.
No particles seem to spontaneously appear from nothing or disappear into nothing. The principles of conservation of mass and the conservation of atoms are considered.	
Chemical change in particles leads to change in the electrodes' mass and structure. The zinc electrode becomes smaller, the copper electrode becomes bigger.	
There is no visualisation of a flow of electric current only from one half-cell to another.	Conductivity of the external electric circuit and the salt bridge is not explicitly shown in the animation. Additional information is available as a pop-up window, where both the processes of conductivity in metals and in electrolytes are explained.

two electrons are released. These same two electrons move through an envisioned "electron channel" towards the copper electrode, which is a questionable construct of electric conductivity in metals. Also the copper electrode is represented as an unaffected continuum. A copper ion from the solution moves towards the charged electrode. Together with the disappearance of the two zinc-generated electrons, a copper atom is formed and disappears into or behind the copper electrode. Similarly this second electrode does not change throughout the process. The zinc electrode does not appear to become smaller, nor does the copper electrode appear to get larger. It is obvious that both electrodes have no more in common with the redox reaction than the external wire circuit or the salt bridge. The salt bridge exists, but it is not involved in the dynamics of the process. Particles or charges are not transported via the salt bridge, although the salt bridge seems to be the same as the external circuit. In interpreting the picture of the external circuit ("the electron channel") only electrons can be transported. The salt bridge looks the same, since ions seem to be too large for passing the salt bridge. Even the transport of charges in electrolytes as a free-flow of electrons is an often-documented misconception among students. …

But why then do we ”see” what we believe we see? Our “expert knowledge” leads us to perceive what we wanted to see: An animated illustration of the Daniell cell. Within seconds we reconstruct our knowledge using the impulse of the animated picture to obtain the correct view. The observed content is no longer of interest to us. Unfortunately, we can’t expect the same for our students.

Students’ alternative ideas revisited

may no longer be any misunderstandings, but can we be confident in this belief? If we view model-based thinking as a serious task in scientific learning, we need to recognise that the above-mentioned animations are not the models but merely illustrations of the scientific model; it is just a teaching model (Justi and Gilbert, 2002b). The scientific models, or scientific theories, as we may call them, are the ideas behind: The scientific models of particles, atoms and atomic structures, or the model of electron-transfer. Teachers will recognize quite quickly where illustrations and scientifically accepted models depart from one another. This, however, cannot be expected from students. In most cases, students do

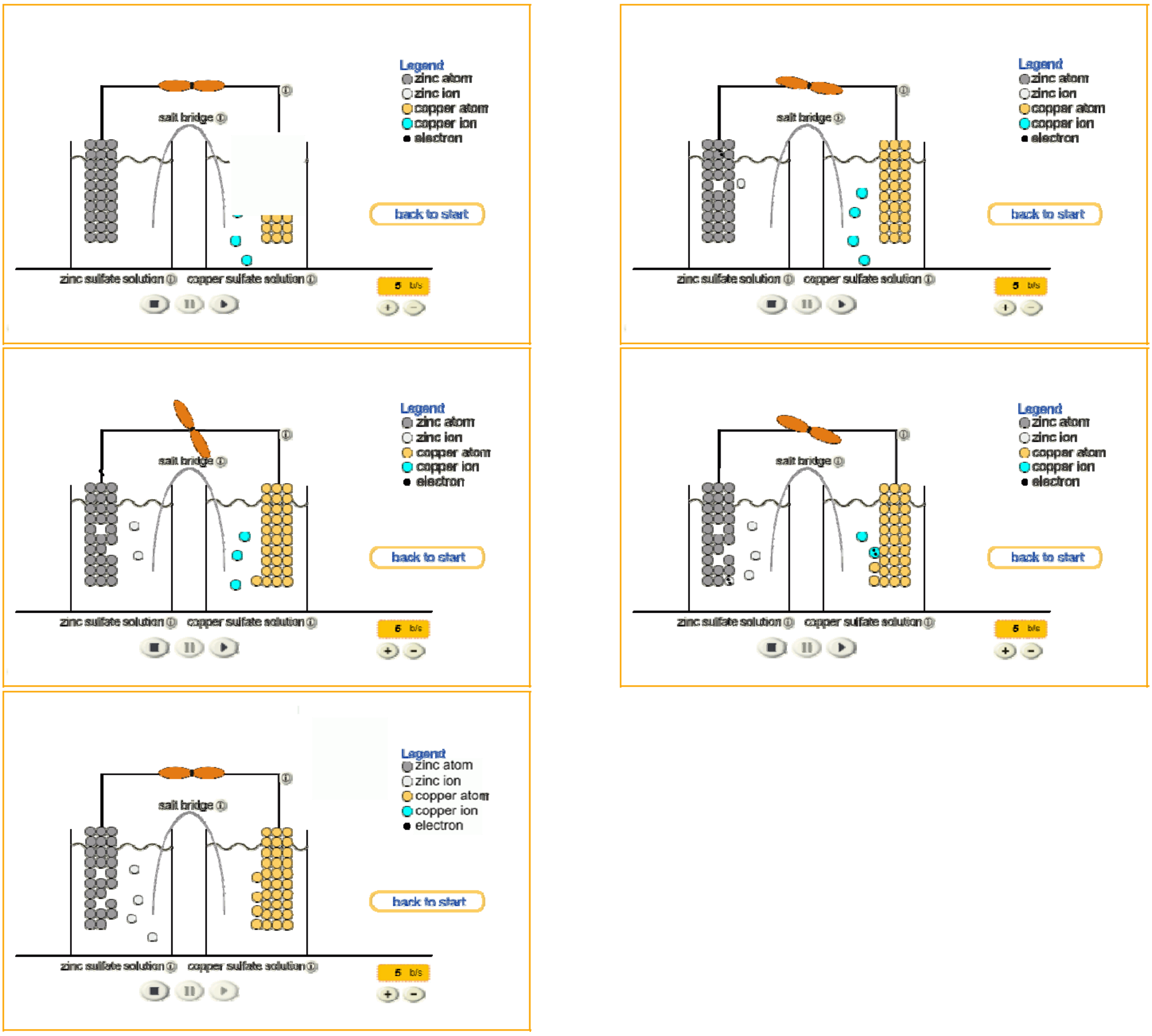

Figure 2. Draft of an animation on the Daniell cell (Pietzner, Eilks, & Witteck, 2008). Originally produced in German, but an English version is also available.

You may think that our interpretation of the above-discussed animation is much exaggerated. This may be true. One may think this is only a model. Models always use shortcuts and simplifications to represent its target (van Driel and Verloop, 1999). If a model is sufficiently discussed and reflected upon in the classroom, there not have a sufficiently-developed understanding of scientific models and modelling (Grosslight, Unger, Jay and Smith, 1991), unfortunately this may also be true for some teachers (e.g. van Driel and Verloop, 1999; Harrison, 2000; Justi and Gilbert, 2002a and b). In the same vein, students lack a developed understanding of the processes occurring in the submicroscopic world.

Empirical research has revealed that there are many alternate beliefs that students hold about matter and chemical change. These results consequently suggest many points to keep in mind when viewing animations as a potential, helpful tool for learning. Table 1 gives some selected results, which may be important for understanding the visual representations of the Daniell cell discussed above. However, it is very difficult to create a visual aid both showing the processes within the Daniell cell and also recognizing all the consequences of students' alternate beliefs. Simplifications appear to be necessary to reach some kind of clarity for the learner. But which kind of simplification is acceptable, and which will only serve to nurture students' alternate beliefs? Of course, we don't have a definitive answer. But to start a discussion, figure 2 shows a draft visual aid. Table 2 discusses some results from empirical research which had been taken into consideration, but shows also some compromises.

IMPLICATIONS

Using our criteria, even the second visual aid is far from perfect; even here compromises were necessary. The purpose of this paper is not to explain how a perfect simulation of the Daniell cell should appear. Rather it discusses how difficult it is to create a potentially-helpful visual aid for students to learn chemistry. Our example also shows that it is often easier to make progress by considering the results from empirical research. Another lesson we can derive from the above discussion is that it can be very risky to use information technology and visual aids which have not been thoroughly considered and tested to identify any potential problematic interpretations from the student's point of view. Animations too often seem to have a greater potential to foster misconceptions than to promote scientific understanding, especially if they are constructed without sufficient reflection on the learners' perspective and pre-knowledge.

Appendix 1 offers different examples for animations of Daniell's voltaic cell in different languages. If we consider these examples from a "naïve" point-of-view, we encounter many interesting interpretations. This is the same viewpoint used by students who know little about the chemical principles behind the visual aids, and who do not have a developed understanding of model use. Such an activity to write down a naïve interpretation of pictures and animations and to compare them to research results proved to be a fruitful exercise in teacher training seminars.

It is easy to be distracted into making all our images colorful, attractive and animated. This seems to be the motivation of many Internet sources. But, it is surely more important that the animations should not be misleading.

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Appendix 1. ***Animations on the Daniell cell from the internet; last access (20 June 2008)***

1. www.chemgapedia.de/vsengine/vlu/vsc/de/ch/13/vlu/echemie/galvanische_elemente/batterie.vlu/Page/vsc/de/ch/13/pc/echemie/galvanische_elemente/daniellapplet.vscml.html
2. www.ltam.lu/chimie/DaniellElementCD.html
3. www.mhhe.com/physsci/chemistry/essentialchemistry/flash/galvan5.swf
4. www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/electroChem/volticCell.html
5. www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/electroChem/voltaicCell20.html
6. www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animations/CuZncell.html
7. www.edunet.tn/ressources/resdisc/physique/monastir/pile/epd.htm
8. http://www.chemie-interaktiv.net/html_flash/redox.swf
9. www.chempage.de → „Theorie" → „Galvanische Zelle"

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The Effects of Problem-Based Learning Instruction on University Students' Performance of Conceptual and Quantitative Problems in Gas Concepts

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This study aimed at investigating effects of Problem-Based Learning (PBL) on pre-service teachers' performance on conceptual and quantitative problems about concepts of gases. The subjects of this study were 78 second year undergraduates from two different classes enrolled to General Chemistry course in the Department of Primary Mathematics Education a State University in Turkey. Nonequivalent pretest-posttest control group design was used. One of the classes was randomly chosen as experimental group (40), took PBL instruction, and the other was control (38) group, took traditional instruction. Students' achievement of conceptual and quantitative problems in chemistry was measured by Conceptual Problems Gases Test (CPGT) and Quantitative Problems Gases Test (QPGT**)** as pre and post-tests. The analysis of results showed that students in experimental group had better performance on conceptual problems while there was no difference in students' performances of quantitative problems. The results of the study are discussed in terms of the effects of PBL on students' conceptual learning.

Keywords: Conceptual Problem, Quantitative Problem, PBL, Conceptual Learning, Science Education

INTRODUCTION

Recent researches into science education have investigated both what students learn and how they learn it. Although much research has examined student conceptual understanding, the connection between conceptual understanding and problem solving skills has not been as well studied. Conceptual learning is the process of acquiring a better understanding in which concepts are exposed to the impacts of new data. It seeks to use the new knowledge to improve the concepts that organize our thoughts. A conceptual problem is a problem of which solution requires understanding of the concepts rather than an algorithm. As for a quantitative problem, it requires the student to manipulate a formula or work through an algorithm to find a numerical solution to the problem (Nakhleh, 1993).

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Chemical educators and teachers have often assumed that success in solving quantitative problems should indicate mastery of a chemical concept (Nakhleh, 1993). However, some researchers (e.g. Nurrenbern and Pickering, 1987; Pickering, 1990; Sawrey, 1990) suggest that there is little connection between solving a quantitative problem and understanding the chemical concept behind that problem. These studies strongly suggested that our current methods of teaching chemistry are, perhaps, not teaching chemistry, but teaching how to get answers to selected algorithmic problems (Nakhleh, 1993; Nurrenbern and Pickering, 1987; Pickering, 1990; Sawrey, 1990). Nurrenbern and Pickering (1987) also pointed out that teaching students how to solve quantitative problems about chemistry is not equivalent to teaching them how to solve related conceptual problems. Therefore, what problem solving is, what purpose it serves in chemistry instruction, and how more students can be enabled to become successful solvers should be reconsidered.

A common complaint heard from the teachers is that their students seem lack the ability or motivation to go beyond factual material to a deeper understanding of course material. The reasons for superficial rather than deep understanding on the part of students are many, including how we test, what expectations we set, and what learning materials we use when we teach. There were some attempts to find materials to help students achieve in-depth knowledge of the concepts. One of this material is problem solving. Standard college textbook problems in science and other disciplines tend to reinforce the students' naive view of learning because they can successfully answer homework end-of-chapter problems through memorization of facts and equations and using novice "pattern-match" problem-solving techniques (Duch, Groh and Allen, 2001). Typical problems do not foster the development of effective problem-solving and conceptual learning (Heller & Hollabaugh, 1992) nor do they challenge students to develop critical thinking skills and logical reasoning (Mazur, 1996).

To better understand what is meant by problem solving it is helpful to examine closely at the nature of problems. Although problems can differ in many ways, they all can be considered as having three characteristics (Johnstone, 2001). First, there is an initial or present state in which we begin. Second, there is a goal state we wish to achieve. Finally, there is some set of actions or operations needed to get from the initial state to the goal state. If one or more of these three components is missing or incomplete, we have a problem. There are eight possible permutations of the three components of a problem (Table 1), but the first of these is not really a problem if we accept the definition above, that one component must be missing or incomplete to constitute a problem (Johnstone, 1993).

However, the situation designated as Type 1 is what we commonly call a problem. Many academic 'problems' are of this kind: all the necessary data is given, the method is familiar and the goal is explicitly stated. They are algorithmic, following well-trodden paths, using familiar formulae and common mathematical techniques.

In order to solve a chemistry problem in an acceptable manner, the problem solver must have both conceptual scientific knowledge and procedural knowledge (Gabel, 1994). However, many studies showed that students frequently do not use conceptual understanding in solving chemistry problems; these studies also provided evidence that students were limited in their ability to solve distant transfer problems without an in-depth understanding of relevant chemistry concepts. Instead of solving problems on the basis of conceptual understanding, they use algorithms and formulas to arrive at correct answers. Hence, chemistry educators have always been interested in enhancing students' understanding of chemical concepts (Gabel, 1994). Different methods have been proposed for doing this. One of these methods is problem-based learning (PBL). It aims to help students develop higher order thinking skills and a substantial disciplinary knowledge base by placing students in the active role of practitioners confronted with a situation that reflects the real world (Maudsley and Strivens, 2000; Şenocak, 2007).

It is a method of instruction that uses ill-structured problems as a context for students to acquire problem solving skills and basic knowledge (Banta et al., 2000). PBL is a way of learning which encourages a deeper understanding of the material rather than superficial coverage, and also it is a problem-oriented learning by which students can not only get basic knowledge while learning, but can also experience how to use their knowledge to solve a real world problems (Yeung et al., 2003; Ram, 1999). Besides PBL aims improve students' ability to work in a team, showing their co-ordinated abilities to access information and turn it into viable knowledge.

A crucial aspect of PBL is the actual design of problem to be solved (Jonassen, 2000). According to

Table 1: Classification of problems (Johnstone, 1993).

Type	Data	Goal	Method
1	Complete	Clear	Familiar
2	Complete	Clear	Unfamiliar
3	Incomplete	Clear	Familiar
4	Complete	Unclear	Familiar
5	Incomplete	Clear	Unfamiliar
6	Complete	Unclear	Unfamiliar
7	Incomplete	Unclear	Familiar
8	Incomplete	Unclear	Unfamiliar

Greenwald (2000), the best way for students to learn science is to experience challenging problems and the thoughts, and actions associated with solving them. In a successful PBL, choosing an appropriate problem is curricial for students to go beyond a superficial understanding of the important concepts and principles being taugnt (Duch, Groh and Allen, 2001; Ram, 1999). If students are given a challenging task (solving of an ill-structred problem) engaging them, they will learn to solve problems and they will acquire the associated knowledge in order to solve the particular problem. At the heart of true PBL is an ill-structured problem that must be based in compelling, real world situations, generates multiple hypotheses, exercises problem-solving skills and requires creative thinking. In other words, ill-structured problems are those where the initial situations do not provide all the necessary information to develop a solution, and there is no one correct way to solve the problem (Chin and Chia, 2006; p.46). Some researchers stated that problem solving using ill-structured problems motivates to students and encourages understanding the epistemology of the discipline (Ram, 1999; Wilkinson and Maxwell, 1991).

In PBL, students work in groups each taking his or her responsibility for a certain part of the task (Sluijsmans et al., 2001). The small group setting used in PBL encourages detailed look at all issues, concepts and principles contained within problem. The time spent outside of the group setting facilitates the development of skills such as literature retrieval, critical appraisal of available information and seeking of opinions of peers and specialists. PBL encourages students to become more involved in, and responsible for, their own learning, and most students and faculty report that this is highly enjoyable way to learn and teach. In PBL process students use self-selected resources such as journals, online resources, text books, other library resources and discus more than traditional students (Albesene and Mitchell, 1993; Vernon and Blake, 1993). It promotes student interaction and teamwork, thereby enhancing students' interpersonal skills (Bernstein et al., 1995; Pincus, 1995; Vernon, 1995) such as working with group dynamic, peer evaluation, and how to present and defend their plans (Delafuente et al., 1994).

The typical learning process followed in a PBL environment is defined by Visser (2002) as follows:

Students begin with the problem - without any prior experience in dealing with the problem. Each group of students will meet with a facilitator to discuss the problem.

The facilitator presents a limited amount of information about the problem, and the group is charged with the task of identifying the different aspects of the problem by asking the facilitator questions to elicit information relevant to the problem.

Students work with the facilitator to generate and refine hypotheses related to the problem's potential solution. The facilitator's role is to model hypothesis-driven reasoning skills.

Students determine "learning issues" that the group decides are relevant and that they need to learn more about to find an acceptable solution to the problem.

The groups are then asked to assign tasks to each member of the group for researching each of the different "*learning issues*" they have identified.

Group members engage in self-directed learning by gathering information related to the assigned learning issues from a variety of different sources.

After each of the group members has conducted the necessary research related to the "learning issue" they were assigned, the group members report their findings to each other. They reconvene and re-examine the problem, applying newly acquired knowledge and skills to generating a formal solution to the problem.

Once the formal solution has been presented to the class and the facilitator, students reflect on what they have learned from the problem and on the process used to resolve the problem presented.

The importance of the teacher in the success of PBL is frequently emphasized in the literature.

The role of the teacher is very different from the usual teachers' role in PBL. For an affective implementation of PBL, teachers must adopt new roles that are frequently very different from those of their past. Rather than being a "context expert" who provides the facts, the teacher is a facilitator, responsible for guiding students to identify the key issues in each case. The teacher also selects the problem, presents it to the students, and then provides direction for student research and inquiry.

PBL was initially designed for graduate medical school programs and then it was adapted for use in other diciplines. Although it is an old and well established approach in medical education, its application in science education could be considered as quite new. In recent years, studies emerged about the use of PBL in science education. For example, there have been studies of PBL in science teacher training (Gallagher et al., 1995; Peterson & Treagust, 1998), teaching chemistry (Ram, 1999; West, 1992; Senocak, Taskesenligil & Sozbilir, 2007)), biochemistry (Jaleel, Rahman, & Huda, 2001), analytical chemistry (Cancilla, 2001; Yuzhi, 2003), electrochemistry (Ying, 2003), and biology (Soderberg & Price, 2003).

One of the studies of the application of PBL in chemistry teaching is by Dods (1997). He investigated the effectiveness of PBL in promoting knowledge acquisition and retention. A total of 30 students from a biochemistry course at the Illinois Mathematics and Science Academy participated. Course content was delivered via PBL, traditional lecture, and a combination of PBL and traditional lecture. Data were gathered using a pre- and post-course self-evaluation of student understanding and a measure of depth of understanding. It was found that content coverage was promoted by lecture, but that PBL was more effective than both traditional lecture and a combination of PBL and traditional lecture in promoting comprehensive understanding of important biochemical content.

Senocak, Taskesenkigil and Sozbilir (2007) carried out a PBL study on teaching gases to procpective primary science teachers through PBL. That study aimed to compare the achievement of prospective primary science teachers in a problem-based curriculum with those in a conventional primary science teacher preparation program with regard to success in learning about gases and developing positive attitudes towards chemistry. The results obtained from the study showed that there was a statistically significant difference between the PBL and conventional groups in terms of students' gases diognastic test total mean scores and, their attitude towards chemistry, as well as PBL has a significant effect on the development of students' skills such as self-directed learning, cooperative learning and critical thinking.

Problem solving is the process used to solve a problem. Since PBL starts with a problem to be solved, students working in a PBL environment should be skilled in problem solving or critical thinking. One indicator of effective problem-solving skills is the ability to transfer reasoning strategies to new problems. Patel et al. (1991) asked traditional and PBL students to provide diagnostic explanations of a clinical problem. They revealed that students in the PBL programme were more likely to use hypothesis-driven reasoning than were students in a traditional curriculum. Another aspect of problem-solving skills is being able to define what the problem actually is, especially with ill-structured problems. This is called problem finding and is the aspect of problem solving that refers to identifying the problem. Gallagher et al. (1992) compared gifted students who were traditionally instructed with students in a PBL class on problem-solving skills, they found that PBL students were more likely to include problem finding as a step when presented with a novel ill-structured problem. Although it is accepted that PBL effects positively students' problem solving skills, but stil researches on the influence of PBL on students' problem solving skills is limited. Therefore, the purpose of this study is to investigate effects of Problem-Based Learning (PBL) instruction on undergraduates' performance on conceptual and algorithmic questions about concept of gases. The study emanates from the hypothesis that PBL has a positive influence on students' achievement in conceptual problem solving. Two research questions investigated were as follows:

1. Is there a significant mean difference between the effect of PBL and traditional instruction on undergraduate students' conceptual problems related to gases law when their pre-CPGT scores were used as a covariate?
2. Is there a significant mean difference between the effect of PBL and traditional instruction on undergraduate students' quantitative problems related to gases when their pre-GPGT scores were used as a covariate?

METHODOLOGY

Subjects

The subjects of this study were 78 second year undergraduates (aged 18 to 21 years; mean=19.20) from two different classes enrolled to General Chemistry course in the Department of Primary Mathematics Education. One class was randomly assigned to the experimental group (n=40) while the other group formed the control group (n=38). Students in the experimental group were instructed with PBL, while students in control group received traditional instruction. General Chemistry is a 5 hour lecture per-week and a compulsory course for all undergraduate students in the second year. Gases Unit is covered during the fall semester. Topics related to gases covered were gas pressure and its measurement, empirical gas laws, the ideal gas law, using ideal gas equation to solve problems, law of partial pressure, diffusion and effusion rates of gases, kinetic-molecular theory and real gases. All students were taught by the same instructor (the first author) and both of the groups received 10 hours instruction.

Instruments

In order to address the research questions, a paired exam which is composed of conceptual and algorithmic problems on gases laws was administered to the subjects before and after teaching. The test used in the study described below.

Conceptual Problems Gases Test (CPGT) and Quantitative problems Gases Test (QPGT) cover the instructional objectives for the unit of gas concepts. Each test included 19 multiple choice items. Some of the test items were taken from Bodner (2001). The tests were evaluated by two instructors to appropriateness of items for content validity. The Cronbach's alpha reliability of the tests was found as 0.84 and 0.77 for QPGT and CPGT respectively. Five examples for each test are given in Appendix C.

Treatment

This study was conducted over a 10 lecture hours. The experimental and control groups were given CPGT and QPGT as pre-tests at the beginning of the study. In the control group, instructor used lecture/discussion methods based on students mostly taking notes and asking questions where they have difficulty in understanding. After instructor's explanation, some concepts were discussed by instructor-directed questions. The instructor also solved some problems during lecturing and worksheets, which included some conceptual and quantitative problems, were also distributed to all students. All completed worksheets were checked, corrected and returned back to the undergraduates to review their responses.

Undergraduates in the experimental group were assigned into ten heterogenic learning teams (four members in each) based on their previous exam results. One week prior to the treatment the instructor provided information about PBL instruction, gave 10 problems cases (scenarios) developed by Şenocak (2004), and the way to solve this kind of problems was explained by the help of an example problem case. Table 1 provides the names, aims and the target concepts of each problem case. The names, aims and the target concepts of each problem cases and three sample problem cases (scenarios) were given as Appendix A and B respectively. Further, sources such as department and university libraries, general chemistry books and several web sites available on the internet were also provided. Students were required to make research on individual bases about every problem case before coming to the class. Only one problem case was covered in each lesson. Students were required to come to a group consensus on the problem case at hand by discussing their individual findings with the findings of the other members in their groups and then to write down their solutions about the problem case into the study sheets. After every group completed this phase, the lecturer asked randomly selected three or four groups to share their findings with the class. Each group is required to change their spokesman when they were given a new opportunity to speak. This process was repeated for every problem case. The remaining lecture time after the investigation of each problem case was spent by solving the related problems from the course textbook.

RESULTS

Based on the data obtained by the CPGT and the QPGT, the students' mean and standard deviation for pre and post test scores for experimental and control groups were shown in Table 2.

The independent sample t-test was used to determine whether there was a statistically significant mean difference between experimental and control groups for the pre-CPGT and pre-QPGT at 0.05 levels. No statistically significant difference between the mean scores of groups with respect to previous achievement of conceptual problems ($t_{(76)}$=0.423; p>0.05) and quantitative problems ($t_{(76)}$=0.636; p>0.05) was found indicating that students in the experimental and the control groups have similar achievement on pre-CPGT and QPGT. In order to investigate the effects of PBL approach on students' achievements on conceptual and quantitative problem about gases, MANCOVA was run on instructions, by taking the pre-tests scores as covariates. Before conducting the analysis of MANCOVA, the covariates were examined. According to Weinfurt (1995), a covariate should be used only if there is a statistically significant linear relationship between the covariate and dependent variables. Therefore, the condition has been tested with Pearson correlation between pre- and post-CPGT scores and pre- and post-QPGT scores. Pre-CPGT scores have significant correlation with post-CPGT scores (r=+0.434, N=78; p<0.01) and pre-QPGT scores have significant correlation with post-QPGT scores (r=+0.321, N=78; p<0.01). Hence, pre-tests scores were used as covariates.

One of the assumptions of MANCOVA is the homogeneity of covariance matrices. In order to test this assumption, Bax's Test was used. This analysis revealed that observed covariance matrices of dependent variables are equal across the experimental and the control groups (*F*=0.383; p>0.05). Therefore, this assumption was not violated. Levene's Test was used to check the assumption that error variance of dependent variables is equal across the experimental and control groups. All significant values for dependent variables, post-CPGT scores (F (1, 76)=0.143; p>0.05) and post-QPGT scores (F (1, 76)=0.113; p>0.05), were greater than 0.05, suggesting the equality of variances assumption was not violated. After checking whether assumptions were violated, Hotelling's T was used to test the effects of PBL instruction and traditional approach on students' conceptual and quantitative gas problems. The results showed that there were significant differences between the dependent variables in the teaching methods used (Hotelling's T=0,151, F (2, 73)=5,502; p<0.05; η^2= 0,131). Therefore, follow up ANCOVA was needed to decide which dependent variable in responsible for this significance. Table 3 and 4 provides the summary of ANCOVA comparing the mean scores of students' performances both in the experimental and the control groups with respect to the post-CPGT and post-QPGT scores, respectively.

The analysis showed that students' pre-CPGT scores have significant effects on their post-CPGT scores (F (1, 74) = 14,744; p<0.05 ;η2 = 0,167). The results also indicated significant treatment effects (F (1, 74) = 10,326; p<0.05; η^2=0,122). The students in the

Table 2. Descriptive statistics for pre-post-CPGT and QPGT scores

Group	n	Pre-CQGT		Pre-QPGT		Post-CQGT		Post-QPGT	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
CG	38	10.42	2.24	10.13	2.93	12.55	2.47	15.16	2.14
EG	40	10.23	1.85	10.52	2.52	14.05	2.30	15.80	2.31

CG: Control Group, EG: Experimental group

Table 3. **Summary of ANCOVA comparing the mean post-CPGT scores of the students in the experimental and the control groups.**

Source	df	Mean Square	F	P	η^2
Corrected model	3	50,637	11,598	0,000*	0,320
Intercept	1	110,379	25,282	0,000*	0,255
Instructions	1	45.081	10.326	0.02*	0,122
Pre-CQGT	1	64.589	14.744	0.00*	0,167
Error	74	4.366			
Total	78				
Corrected Total	77				

*Significant at p<0.05

Table 4. **Summary of ANCOVA comparing the mean post-QPGT scores of the students in the experimental and the control groups.**

Source	df	Mean Square	F	P	η^2
Corrected model	3	16,451	3,622	0,017*	0,128
Intercept	1	344,279	75,793	0,000*	0,506
Instructions	1	6,397	1,408	0.239	0,019
Pre-CQGT	1	25,800	5,680	0.020*	0,071
Error	74	4,542			
Total	78				
Corrected Total	77				

*Significant at p<0.05

experimental group who were subjected to PBL instruction demonstrated better performances (adjusted mean = 14,066) on post-CPGT scores than the control group students who were subjected to traditional instruction (adjusted mean=12,536).

The analysis showed that students' pre-QPGT scores have significant effects on their post-QPGT scores ($F(1, 74)=5{,}680$; $p<0.05$; $\eta 2= 0{,}071$). The results also indicated that there is no significant treatment effects ($F(1, 74)=1{,}408$; $p>0.05$; $\eta 2=0{,}019$) on the post-QPGT scores. This means there are no significant differences between the students in the experimental group who were subjected to PBL instruction and students in control group students who were subjected to traditional instruction.

DISCUSSION

The aim of PBL is to help students to think, to solve problems and to enhance their thinking skills by constructing real or resembling situations pertaining the concepts to be learned. This study aimed at investigating effects of Problem-Based Learning (PBL) instruction on pre-service teachers' performance on conceptual and quantitative problems about concepts of gases. The results show that although there is not a statistically significant difference between the quantitative success rates of pre-service teachers, there is a statistically significant difference between the conceptual success rates of pre-service teachers on the topic of gases. One of the most favorite research area among the studies on chemical education is the issue of how chemical topics were learned and how could the level of conceptual learning be increased. Recent studies (Markow and Lonning, 1998; Harrison and Treagust, 2001; Bilgin, 2006) show that the requirement of conceptual learning of chemistry by students is gaining importance. Several chemists perhaps share the opinion that the students have a tendency to memorize solution paths of algorithmic problems without realizing the conceptual knowledge contained in the problems (Beall and Prescott, 1994).

Learning activities prepared by the traditional problem solving approaches generally focus on a small part of a certain topic. PBL activities, on the other hand, require an organization since they have a wider scope. Although students are expected to reach a certain result in learning by problem solving approach, there is not such a definite expectation in PBL. The important point for students is to attain some of the learning objectives by making use of the problem whether or not they reach the certain correct answer (Savin-Baden, 2000). The traditional approach of teaching a concept involves the stages of the provision of the term that denotes the concept to the student, making the definition of the concept, stating the descriptive and discerning properties of the concept in order the definition to be understood, enabling students to find examples both related and unrelated to the concept. This approach is not sufficiently effective in teaching concepts since it is not enough for students to define concepts and memorize them in order for them to see the concepts and the relationships among them. One should enable students to discover scientific knowledge themselves and to discuss them among themselves by creating appropriate circumstances for them to work like scientists (Bodner, 1986). Thus, the students will gain the conceptual learning skills by avoiding the need to memorize them. Researchers have developed a variety of learning approaches, including PBL, in order to reach this aim.

The most prominent aim of the PBL is to make students active, free and self-learning individuals rather than being passive recipients of the knowledge (Barrows, 1986; Gallagher et al*.,* 1995; Boud and Feletti, 1997). PBL also enables students to evaluate themselves while trying to help them to achieve this aim (Sullivan and Dunnington, 1999). Meanwhile, PBL approach requires working cooperatively (Duch et al., 2001). Its justification lies on the fact that gaining merits including trading information, communication and collaborative working skills will be helpful for students in their lives in the future (Cancilla, 2001). Students solve problem situations by working in groups. In this study, the participants of the experimental group were divided into ten heterogenic groups and the participants investigated the problem situations with their groups during the implementation. Students' working collaboratively in groups in PBL creates an appropriate environment for them to learn the concepts by providing them an opportunity to investigate others' comments and to discuss among themselves (Will, 1997).

Based on the findings of the study, following suggestions could be made;

1. The conceptual and quantitative success rates of mathematics pre-service teachers' on the topic of gases in the course of General Chemistry have been investigated by adopting a PBL approach. It is suggested that it might be helpful to investigate the effects of this approach on teaching other concepts in chemistry courses or the success rates of other courses and to examine its effectiveness in practice.
2. It is suggested that one could employ PBL approach in order to help students to develop their communicative and collaborative working skills and their skills on accessing information and utilizing it.
3. It is suggested that PBL could be useful in laboratory teaching since it includes a range of activities such as collaboration, comprehension and analysis of the events, developing hypotheses, collecting information and analyzing it and making experiments.
4. This study was made at undergraduate level. It is suggested that it might be helpful to investigate and collect data on how practical and implementable PBL is in other educational stages (primary and secondary schools).

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Appendix A. Three sample problem cases (scenarios) used in the study.

WATER PUMP

Working processes of water pump and suction pump base on air pocket. When arm of the suction pump is pressed, piston in the cylinder goes to up. The water takes the place of air pocket which occurs when the piston is pulled up. Thus water in the well can rise. Whatever pressure is applied to the arm of the water pump, water can't go up more than 10 m 33 cm..In the 1600's, the scientists began to research why water in the well can't be raised more than 10 m 33 cm. If they had accomplished to increase water level more than 10 m 33 cm, they would have utilized that in many areas. Because technological devices were very poor that days in comparison to today, water pumps were very important devices. One of the scientists studying in this matter was Torricelli who was Galileo's student. Thanks to his researches on this matter, Torricelli put forward that 1 atmospheric pressure equals 76 cmHg. How might be Torricelli attain this idea?

Key Words: Water pump, Torricelli, Atmospheric pressure

BUBBLES

Divers take scuba gear that contains compressed air (nitrogen-oxygen) when they dive in deep water. When actions of a diver who swims in deep sea are examined, it is seen that the bubbles depart from mouth of the diver and these bubbles rise up. It is seen that bubbles' volumes gradually increase while those are rising up and reach several times bigger than that in the beginning. There isn't any change in the chemical construction of the matter or matters inside the bubbles when those rise. What can be the reason(s) of the change of the bubbles' volume? (Assume that the temperature in the sea water remains the same as all points of the sea)

Key Words: Compressed air, Volume

CONFUSION OF AN ENGINEER

A chemical engineer wanted to carry out an experiment. For this experiment he needed nitrogen gas which had 135 atm pressure and 92,4 kg weight. The engineer had a vessel with 1m^3 in which he could store the gas. But the engineer had 92,4 kg of nitrogen gas at 81 atm pressure at 300 K temperature. The engineer wonders how he could increase the pressure of gas to 135 atm without changing the volume and the amount of gas. In order to solve this problem, he conducted some mathematical calculations assuming that nitrogen behaving as an ideal gas. He found that if he heats up the gas to 500 K, the pressure of gas will reach to 135 atm. Once he heated the gas up to 500 K, the pressure of gas reached to 140 atm instead of 135 atm. The engineer confused and started to think about what was the mistake he made. What do you think about this case? Why the pressure of the gas become 140 atm instead of 135 atm at 500 K? (Assume that the engineer did not make any mathematical calculation mistake)

Key Words: Perfect gas, Pressure, Temperature

Appendix B. The contents of problem cases used in the study

Week	Class Time	Name of Problem Case	Explanations	The Target Concept
First Week	1	Water pump	Comprehension of the gas pressure by the help of open air pressure	Air Pressure Barometre Manometre
	2	Bubbles	Comprehension of the basic gas laws	The relationship between pressure and volume
	3	Soccer ball	Comprehension of the basic gas laws	The relationship between heat and pressure
	4	A journey at A hot weather	Comprehension of the basic gas laws	The relationship between heat and pressure
	5	The doubt of an Engineer	Comprehension of the properties of ideal a absolute gases	Ideal gas Absolute gas
Second Week	1	Balloons	Comprehension of the density relationships of gases Comprehension of the difference among solid, liquid and gas densities and gas densities	Gas densities
	2	Cars and air Pillows	Comprehension of the gas behaviour by investigating the chemical reactions where gases acts as reactants or end-products	Gases in chemical reactions
	3	A Bicycle pump	Comprehension of the events in the theory of gas kinetics	Kinesthetic theory
	4	Missing water	Comprehension of the events in the theory of gas kinetics	Kinesthetic theory
	5	Ammonia and ethyl acetate	Comprehension of the gas properties related to the theory of gas kinetics	Expansion of gases

Appendix C. Examples of Quantitative Problems

1) 0.1 mol hydrogen gas at 2.00 atm and 127 ^oC has 10 L initial volume. If the temperature of hydrogen gas is decreased to -23 ^oC under constant volume, what will be the new pressure of hydrogen gas?

a. 1.25 atm b. 1.5 atm c. 3.25 atm
d. 4.08 atm e. 5 atm

2) There is a helium gas with the volume of 5.51 dm^3 and pressure of 1.015 atm, and a temperature of 24 ^oC in a flexible balloon. When the temperature of the helium is increased to 35 ^0C, the pressure of the helium increases 1.028 atm. In this case, what is the new volume of the helium gas?

a. 4 b. 3.6 c. 4.6
d. 2.8 e. 5.54

3) The equation

$$\mathbf{Zn_{(k)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}}$$

represents the reaction between zinc and hydrogen chloride to produce hydrogen. 156 ml of hydrogen is collected over the water at 20 ^oC and 769 mmHg. The pressure of the water vapor is 17.5 mmHg at 20 ^oC. What is the mass of the hydrogen that is formed in the reaction?

a. 0.5 g b. 0.0129 g c. 1.29 g
d. 2.129 g e. 0.789 g

4) A container with three gases, 8 g of methane (CH_4), 1.806 x 10^{23} molecules of nitrogen (N_2) and 0.5 mol hydrogen (H_2) has the temperature of 0 ^oC and the volume of 1.12 L. What is the partial pressure of the nitrogen?

a. 3 b. 4 c. 8 d. 6 e. 12

5) A gas at 350 K and 12 atm has a molar 12 per cent lesser than that calculated from the perfect gas law. Calculate the compression factor under these conditions.

a. 0,88 b. 1,14 c. 1,64 d. 1,25 e. 1,4

Examples of Conceptual Problems

1) Which of the following graphs don't show a linear relationship for an ideal gas?

a. T vs V graph (n and P are kept constant)
b. P vs T graph (n and V are kept constant)
c. 1/V vs P graph (n and T are kept constant)
d. 1/T vs n graph (P and V are kept constant)
e. 1/P vs n graph (V and T are kept constant)

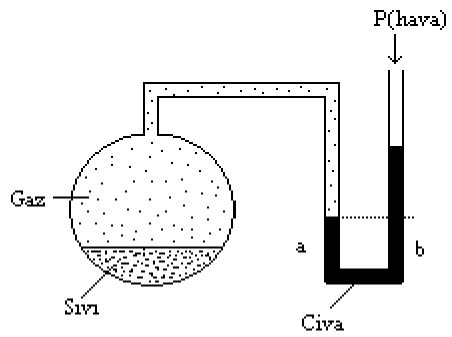
2) The nitrogen (N_2) and oxygen (O_2) with equal masses are placed in two identical containers that have same temperature. In this case, which is the following statement true?

a. The number of the molecules in each container is equal
b. The pressure in the container which contains the nitrogen is more than the pressure in the container which contains the oxygen.
c. The number of the molecules in the container which contains the oxygen is more than the number of the molecules in the container which contains the nitrogen.
d. This question can not be answered without knowing the masses of the nitrogen and oxygen.
e. None of the statement is true

3) Which of the following statements is not one of the basic assumptions related to the kinetic theory of gases?

a. Gases compose of a very large number of minute particles which move freely and rapidly through space
b. The radiuses of gas molecules are very small relative to the average distance between molecules. Therefore, most of the volume of a gas is empty area.
c. Until the gas molecules collide with each other and with the walls of the container, the molecules are in linear motion.
d. The mean kinetic energy of the gas molecules is proportional to the temperature of the gas.
e. All of the statement is true

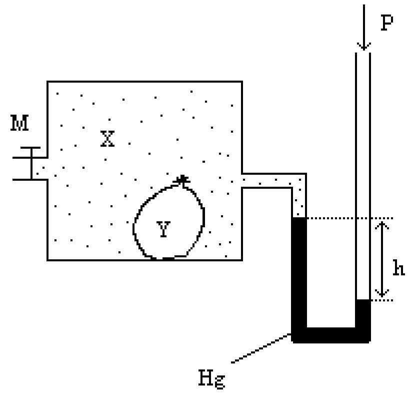
4) It was seen that the level of the mercury in the b arm of the manometer increased as time passed. What can be the reason of this increase?



a. Because the gas liquefied
b. Because the liquid evaporated
c. Because the gas solved in the liquid
d. Because the glass balloon was cooled
e. Because atmospheric pressure was increased

5) X gas and Y gas that is in a flexible closed balloon are in a container which is linked with a manometer. When the M tap is opened,

I. The levels of the mercury (Hg) equal in the arms of the manometer
II. Increases the height of h
III. The balloon in the container puckers



Which is (are) the statement(s) above true?

a) Only I b) Only II c) Only III
d) I and II e) I and III

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Learning to Teach Science Using English As The Medium of Instruction

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Malaysia is currently reforming its education system in line with the government's Vision 2020. Key areas such as science and mathematics education are high on the agenda. However, as considerable world knowledge is written in English, Malaysian preservice teachers are being educated to teach these areas using English as the Medium of Instruction (EMI). This study describes Malaysian preservice teachers' perceptions about their preparation for learning to teach science using EMI at the conclusion of their first year of a new Bachelor of Education Studies (Primary Science) degree. An open-ended questionnaire collected data from 50 Malaysian preservice teachers from a Malaysian institute. These preservice teachers indicated that English vocabulary, grammar, and pronunciation were paramount for their concept development in science education. Self assessments after one year of education also indicated an increase in English-language proficiency towards teaching primary science education (Pre course: M=4.68, SD=1.20; after one year: M=6.38, SD=1.12). Emailing, Internet chatting, short service messaging, and allocating English-only days were considered other ways for increasing such proficiencies. These and other findings are discussed in this paper to provide an understanding on practices that may be incorporated into coursework for enhancing both science education and English-language skills.

Keywords: Literacy, Religion, Science, Sociocultural, Superstition

INTRODUCTION

Malaysia is highly motivated to strengthen its economic position in the world market, which requires developing a world-class quality education system (Rahman Idris, 2005). Attaining scientific literacy must be viewed as central to education reform (Gallagher, 2000; Pattanayak, 2003) as this is considered a way to empower citizens towards economic gain (Ayala, 2005; Jenkins, 1990). A scientifically-literate public can enhance a country's market position (Bischoff, Hatch, & Watford, 1999); however extensive science knowledge is written in English that needs to be accessed by English as Foreign Language (EFL) countries. Hence, education reform in EFL countries are beginning to target the foundational levels of learning such as primary education with specialist teachers who can focus on science education using English as the Medium of Instruction (EMI), which is the thrust of the Ninth Malaysia Plan, 2006 – 2010 (Rahman Idris, 2005). Science education and English literacy development must be core elements in EFL preservice teacher education if economic advancement is a national focus for international engagement.

Science teachers are recognized worldwide as a key to science educational reform (Gallagher, 2000; Goodrum, Hackling, & Rennie, 2001), which requires time, resources, and support for ongoing professional development to promote improved learning outcomes. Indeed, teachers generally aim to make a difference to students' lives (Neal, McCray, & Webb-Johnson, 2001), especially as enhancing students' learning may be linked to effective teaching (Vogt, 2002; Wong, Britton, & Ganser, 2005). The American Association for the Advancement of Science (AAAS, 1993) advocates

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science education standards that require systemic change involving the development of teachers' perceptions of science teaching. The Australian National Science Standard Committee (2002) also recommends professional knowledge, professional practice, and professional attributes as standards for recognising accomplished teachers of science. Addressing proposed standards will require considerable educational reform, particularly in primary science where such education may not be a priority for teachers (e.g., Goodrum et al., 2001). However, "education reform can succeed only if it is broad and comprehensive, attacking many problems simultaneously. But it cannot succeed at all unless the conditions of teaching and teacher development change" (National Commission, 1996, p. 16).

System requirements for primary science education provide a direction for teaching, and present a framework for regulating the quality of primary science teaching practices (Hudson, Skamp, & Brooks, 2005). If system requirements are necessary for guiding science education reform in primary schools then this should also occur for preservice teacher education. The development of preservice teachers' skills for teaching science requires considerable scaffolding with focused attention on the acquisition of pedagogical knowledge and content knowledge (Abell & Bryan, 1999; Bybee, 1997). Institutions involved in preservice teacher education must provide science education courses with outcomes that are promoted as obtainable goals with the content of such courses aimed at presenting current theories and practices for teaching primary science (Hudson & Ginns, 2007).

Although preparation for teaching primary science involves preservice teachers analysing and understanding current theories that underpin a science curriculum and developing adequate pedagogical knowledge and content knowledge (Fleer & Hardy, 2006; Morine-Dershimer & Kent, 1999), EFL preservice teachers have an additional challenge, that is, learning to teach science with links to current education reform measures and learning to teach this subject using EMI (Hudson, Nguyen, & Hudson, 2008). Hence, the Malaysian education system is aiming at addressing simultaneously these two key educational reform measures (i.e., teaching science and teaching science using EMI).

This study explores and describes Malaysian preservice teachers' perceptions about their preparation for learning to teach science using EMI at the conclusion of their first year of a new Bachelor of Education Studies (Primary Science) degree. Fifty preservice primary teachers at a Malaysian institute of education had completed one semester of Malaysian core units that involved Islamic and Asian Civilisation, citizenship studies, strategic and innovative thinking in education, English for academic studies.

The second semester comprised of four units, that is: (1) the development of skills in information and communication technologies; (2) primary curriculum and pedagogy in health and physical education; (3) English for teachers; and, (4) an integrated mathematics and science foundation unit to develop scientific and quantitative literacy. There was also a two-week school-based experience for these preservice teachers to commence forming knowledge of their primary school education system. Even though the first semester was taught in Bahasa Melayu, the second semester was delivered in English with all lectures, readings, workshops, and assessments conducted in English. This required lecturers and preservice teachers to use English as the target language. It was a requirement that these preservice teachers live on campus in the accommodation provided for the duration of each semester.

Data Collection and Analysis

Open-ended questions aimed to investigate 50 Malaysian preservice teachers' perceptions of their preparation for teaching primary science education using EMI. These questions were a means towards understanding respondents' perspectives (see Polonsky & Waller, 2005). This sample (n=50) represented 100% of the total cohort undertaking a Bachelor of Education Studies (Primary Science) degree in a Malaysian institute of education. The questions focused on their motivation to teach English and the importance of teaching science using EMI; their preparation for teaching English and teaching science using EMI; perceived difficulties for learning how to teach science using EMI; potential benefits for Malaysian primary students' learning of science using EMI; and the impact on learning to teach science for developing the preservice teachers' English-language skills. The questionnaire also included a self-assessment scale numbered 1-10 (lowest to highest) for the preservice teachers to indicate their personal development of English before and after their first year of the degree. In the data analysis, themes and categories were coded for each of the questions, and descriptive statistics were used to quantify the data where appropriate (see Hittleman & Simon, 2006).

RESULTS AND DISCUSSION

The open-ended questionnaire was administered in classes at the conclusion of their first year of a Bachelor of Education Studies (Primary Science) degree. The completed responses (88% female; 12% male) provided descriptors of the participants (Malaysian preservice teachers, *n*=50). All preservice teachers except one had completed the Islamic and Asian Civilisation, citizenship studies, strategic and innovative thinking in education, English for academic studies foundational units. Most of these preservice teachers were 21-22 years of age (88%), and 12% were between 22 and 25 years of age.

Motivation for teaching EFL

Most of these preservice teachers (90%) claimed they decided to teach EFL as it was an international language "to help us face and overcome the problems of globalization. We can't follow the development of the world without improving our language" (Participant 44). Others recognised the global need for using EMI: "We need to expose our country to the world by mastering this language" (Participant 7) and that it is an "important medium of communication" (Participant 45). Some indicated the enjoyment of learning English, for example, "I've loved the English subject since I was small" (Participant 15) and "learning a language is fun" (Participant 30). However, 9% of preservice teachers indicated they had not chosen to teach science using EFL as it was an imposed requirement of their course, that is, "Our education system is giving more attention to English" (Participant 15), "This is compulsory in our institute" (Participant 43), and "It is not for me to decide, the 'kementerian' had to decide it early in the year" (Participant 34). Nevertheless, these preservice teachers continued with their studies under these requirements.

Access to science knowledge in the English language was noted as substantial for future employment prospects, to illustrate, "Science information or knowledge is in English. If someone does not understand the English language, she or he will feel lost because she/he cannot compete with people around the world" (Participant 38). The Malaysian Government's Vision 2020 was clear with these preservice teachers, case in point: "everyone should learn English to be a Malaysian citizen toward achieving Vision 2020" (Participant 23).

Benefits and impact on the preservice teachers' development

The preservice teachers acknowledged the necessity for teaching science using EMI, particularly as science is taught in English in higher education (Participant 1). In addition, "Most of the good revision books are in English and it is very hard to get any Malay version books for this subject" (Participant 15). One preservice teacher claimed that science lessons were more interesting as a result of learning English and that it was more suitable to teach science using EMI for the 21st century (Participant 6). Others indicated that teaching science using EMI addresses national directives, for instance, "It is the requirement from government. It is also to prepare the work force to excel in globalization internationally" (Participant 8) and Malaysian "students will achieve the goal of Vision 2020" (Participant 25). Targeting primary students seemed to be relevant as a foundational measure for addressing Vision 2020, to illustrate, "Students will understand science more easily [using English]. Because students at primary school are still at an early stage" (Participant 29). Furthermore, "To benefit the primary students the educational system will be more effective. Good for students' future" (Participant 49). Another preservice teacher stated that targeting primary students will aid Malaysians to "Master the language, master the world" (Participant 50).

Other preservice teachers were coming to terms with how to explain and express themselves in English to primary students studying science education. The following responses in this paragraph represented many of the preservice teachers' thoughts about becoming error free in English grammar and vocabulary. "My vocabulary has improved a lot and I can now write with few grammatical errors" (Participant 15). Even though English is not the "Malaysian's mother tongue" (Participant 18) and the historical fact that "During our school days the syllabus was in Malay and we learnt all the [science] terms in Malay" (Participant 22), the preservice teachers acknowledged their development of English and science. They also recognised the importance of eliminating errors from their English language in order to teach science effectively: "I'm able to talk more fluently than before and I'm not scared that I'll error when I'm speaking" (Participant 22); "I have learnt new words and I'm more sensitive to grammatical errors" (Participant 27); "My English has improved as I learn to teach science in English" (Participant 6); and, "I started sharpening my mind by learning more about English and science" (Participant 9).

These preservice teachers have developed confidence in using English for self study on science topics, that is, "We [are] able to initiate to find and seek for proper explanations of English to teach in science" (Participant 50). Confidence building is key to acknowledging the progress of English language for teaching science education, which appears to be the case in this course: "It has improved my confidence to communicate in English" (Participant 8). This confidence has lead to more confident instructional usage, for example, "I learned to give English instructions and use the appropriate words in the classroom during this course" (Participant 30). These preservice teachers indicated that, as a result of teaching effectively in English, Malaysian primary students will be able to develop "higher-order thinking skills" (Participant 7) and "surf the Internet to get [science] information in English" (Participant 8), which will aid the students to "have a good basic education, which will be very useful in their future" (Participant 17), including "high school education" (Participant 24) so they "can manage themselves in the new environment when they reach university" (Participant 36).

A self-assessment scale provided an indication of the preservice teachers' perceptions of their English-language development as a result of units undertaken in this degree. Before commencing the degree the preservice teachers scaled themselves between 2 to 7 (*M*=4.68, *SD*=1.20), whereas after completing their first year of study they scaled themselves between 4 to 8 (*M*=6.38, *SD*=1.12; Table 1). The increase of 1.70 in the mean score suggested that the participants believed they had improved their English skills after one year of coursework. Yet, it also showed that they recognised they had considerable lengths to go (mean score of 3.62) before perceiving they had achieved optimum English-language development. Even so, they were only one quarter through their degree, hence, achieving a higher self-assessment scale at the end of the four-year degree would be likely. The "before" and "after" self-assessments showed a graded increase that may be expected from a more rigorous objective test. That is, on a scale of 1 to 10, the "after" English development jumped approximately 2 ratings and did not show inflated results, as may be expected in self assessments. Hence, this type of assessment within the Malaysian preservice teaching institutes may have validity.

Table 1. Preservice Teachers' Self-Assessment of their English-language Development

Scale	Before	After
1	0	0
2	2.0	0
3	14.0	0
4	30.0	6.0
5	30.0	18.0
6	16.0	22.0
7	8.0	40.0
8	0	14.0
9	0	0
10	0	0

*Valid percentage of preservice teachers indicating their perceived level of English development as a result of the first year of a Bachelor of Education Studies degree.

Difficulties for learning to teach science using EMI

The main difficulties encountered by these preservice teachers for learning how to teach science using EMI were about having time to learn English with the associated science terminology and the current Western culture: "I am used to speaking in Chinese with my friends. I have my own language at home and I have not much free time to read in English everyday" (Participant 2). This type of comment was indicative of the majority of comments with a further 46% claiming that understanding or "memorising science terms" presented the biggest barrier for learning how to teach science using EMI. In addition, the preservice teachers noted that lecturers also have had to adjust for teaching science content in English, which they previously taught in Bahasa Melayu. This presented another level of difficulty, for instance, "The teacher may not be used to science terms in English as they have been teaching Malay for a long time. Moreover, some teachers may face difficulty in speaking English as it is not their mother tongue" (Participant 1). Similarly, "Students do not understand well. Teachers cannot explain well in English but explain well in their mother tongue" (Participant 49). So the preservice teachers have to overcome their own English-language barrier while some lecturers also grapple with teaching a subject they had taught only in Bahasa Melayu. Those teachers who were strong with English faced the difficulty of getting across the language to their students, "The foundation of English language for students and teachers is not good. Some teachers are good in English but students can't understand them" (Participant 44).

Possible solutions for learning to teach English and for teaching science using EMI

These preservice teachers indicated various solutions for preparing themselves to teach science using EMI. Seventy-two percent indicated that reading different texts had aided their preparation for teaching science using EMI. These texts included English articles, newspapers, novels, magazines, and any available English literature, for example, "I read the bible which is an English version everyday. I jot down the words that I can't understand and read them when I'm free" (Participant 2). There was overwhelming acknowledgement that vocabulary, grammar, and pronunciation were paramount for developing their language. Participant 22 claimed the need to "Enrich my vocabulary. To learn the correct pronunciation. Pamper myself with grammar". "Learning to use the dictionary appropriately and making a draft and ask my friends to check my grammar and structure before pass up my assignment" (Participant 33) were noted as ways to improve vocabulary and grammar. Indeed, peer-assisted learning by reviewing another's assessment pieces was proving to be a valuable method indicated by six participants for enhancing their English competency, to illustrate, "I ask friends to correct my English and find where I have made a mistake" (Participant 37).

The majority of these preservice teachers perceived their preparation for teaching science using EMI involved learning scientific vocabulary on specific topics and the associated scientific names, for example, "I can always refer to the scientific names of the science for example the key words and their meaning through the dictionary" (Participant 12). Using an English-based science dictionary was noted as a way forward. However, some referred their preparation for teaching science using EMI was directly related to learning English without reference to scientific terms. "I must read a lot of English materials and try to speak in English most of the time. I also can refer to people who are better than me if I have a problem regarding this language" (Participant 20). Participant 40 advocated severe measures by trying to "Avoid the use of Malay terms and try to ask friends or lecturers if [we] do not the scientific term" (Participant 40).

Although some considered discussing with friends the science English terms and reading lecture notes in English (Participant 33), two preservice teachers claimed that knowing the science terms was not sufficient enough, to illustrate, "[we] should know and learn term of science in English but [we] also must know how to elaborate the knowledge using the word/term in science" (Participant 38). Nevertheless, there appeared to be some consensus about learning the science terms in English before involvement in lectures on the topic in order to develop a deeper understanding of the content: "Introduce the terms by searching the meaning first is the best way to understand the content later" (Participant 45).

Other supportive suggestions for English-language development included conversing frequently with friends "such as group discussion among friends" (Participant 28) and "trying to speak more English with my course mates" (Participant 37). Participant 8 claimed success in learning English by designating full English speaking days, to illustrate, "I have put effort into improving my competency in English. My friends and I decided Wednesday as English day and speak fully in English on that day. Quite successful". Undoubtedly, speaking English everyday has a role at the institutes outside the immediate coursework, "Try to learn everyday. If there is a change try to use it in our daily lives" (Participant 29). Participant 2 also stated that she prepares herself by communicating in English using electronic methods: "I try to speak with my friends in English and chat with my friends on the Internet by English." These preservice teachers perceived other forms of preparation for EFL teaching that involved listening to the radio (Participants 3, 9, 30, 40, 49), reading grammar books (Participant 5), checking meanings with a dictionary (Participants 17, 21), watching English movies (Participants 24, 27, 50), listening to English songs (Participant 34), and writing frequently in English (Participants 25, 48) including email, Internet chatting and short message service (i.e., sms from cell phones; Participant 36). These multi-media techniques appeared to assist the preservice teachers' language development.

SUMMARY AND CONCLUSION

The preservice teachers indicated in this study that social interaction using English appeared to be a successful way forward for developing the language, which is advocated as a key goal in TESOL education (TESOL, 1997). These preservice teachers claimed that coursework delivered in English, including English-based assessments, allowed them to more effectively construct academic knowledge in the target language. Learning strategies such as Internet chatting and English-only days provided means for enhancing communicative competence. In addition, these preservice teachers needed to understand key scientific terms before a lecture commences so there is greater familiarity when provided new information around such terms. The preservice teachers suggested a wider range of teaching strategies (e.g., listening to the radio, reading grammar books, checking meanings with a dictionary, watching English movies, listening to English songs, and writing frequently in English, including email and short message service) that aided towards facilitating their English skills. Educators need to listen to preservice teachers' testaments of success and incorporate or facilitate such practices in their coursework. Indeed, self-assessments may be used to measure successful attainment of teaching science using EMI within the Malaysian institutes.

Malaysia is at a critical point of education reform and interactions with other education systems may aid in transforming its own education system. To meet this educational reform will require teaching primary science using EMI. This means targeting primary science education concepts and English concepts simultaneously if the Vision 2020 goal is to be reached. Preservice teacher education course construction will be paramount for injecting new educational ideas into the system. Indeed, the education of preservice EFL teachers must be a focus of attention in an effort to obtain quality EFL teaching (Haley & Rentz, 2002; Larsen-Freeman, 2000) and gain access to the world's knowledge base on science. Investigating preservice teacher development during this formative period can aid in refining programs to further enhance such development. The preservice teachers in this study provided information about their preparation for teaching science using EMI that can guide educators' construction of coursework.

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Narrating International and National Trends in US Science Education: An autobiographical approach showcasing Dr. Robert Yager

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This biographical piece is based on a conversation involving Bob Yager, Geeta Verma, and Lisa Martin-Hansen which took place at the National Association for Research in Science Teaching (NARST) conference in March, 2008. The unique aspect of this autobiographical piece is that it highlights Dr. Yager's account about the emergence of the science education field of study and his engagement with the field over a period of more than 50 years. The piece is organized using conversation topics through a biographical narrative format that starts at the beginning of Dr. Yager's career, establishing science education at The University of Iowa, the emergence of Science, Technology, and Society (STS) ideas, existing intersections between STS and Socioscientific Issues (SSI) ideas, his reflections on work with doctoral students, and a consideration of the goals and aims for future directions in the field.

Keywords: Career, Science Education, Science, Technology and Society

FOREWORD

Robert (Bob) Yager is a professor emeritus of science education at The University of Iowa. Dr. Yager received his Ph.D. in Plant Physiology in 1957 from The University of Iowa; an MS in Plant Physiology in 1953 also from The University of Iowa; and a BA in Biology from the University of Northern Iowa in 1950. Interestingly, Dr. Yager was awarded an Honorary Doctorate in Humane Letters from the University of Northern Iowa in December 2008. Dr. Yager began his professional career as a laboratory assistant at the University of Northern Iowa in 1948 as an undergraduate student. After graduating, Bob took a position as a Biology and English high school teacher in Chapin, Iowa, that he held for two years. Soon after, he was hired as a life sciences instructor at The University of Iowa while he worked full time on his MS in Plant Physiology. Following that he served as a basic education instructor in the US Army for two years beginning in 1953. While he worked on his Ph.D. in Plant Physiology, Bob was first employed for a year as a teaching assistant in Botany starting in 1955 and then was hired as Acting Head of Science Education and chaired the science department at the University High School (the laboratory school) at the University of Iowa starting in 1956. Bob began working at The University of Iowa as an Assistant Professor in Science Education after finishing his doctorate degree in 1957. Over the years, Bob earned tenure and promotion as an Associate Professor in 1963 and then full professor in 1967 at The University of Iowa. He continues to be affiliated with The University of Iowa as professor emeritus and work with Visiting Scholars as well as a staff from a five-year

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research project focusing on science teacher preparation and continuing education.

This brief biographical narrative highlights a few key items and is by no means a comprehensive account of his career. A sampling of Dr. Yager's professional awards, funded projects, and other professional contributions including his work with various professional organizations and students are listed here. Bob has received several awards in recognition of his scholarly contributions including the Lifetime of Distinguished Contribution to Science Education through Research Award, National Association for Research in Science Teaching. He received the Carleton Award in 1977– the most prestigious award given by the National Science Teachers Association. He received the Brady Award for Distinguished and Sustained Service to the University of Iowa, in 2001. He received the outstanding Mentor Award from the Association for Education of Teachers of Science, in 2000. Other awards include the Lifetime Distinguished Service, Mathematics/Science Coalition, State of Iowa, in 1999; Significant Scholarly Contributions to the Field of Education, Iowa Academy of Education, in 1999; Vasconcelos Education Award of the World Cultural Council. Victoria University of Wellington, New Zealand, in 1998; and the Distinguished Service Award, International Council of Associations for Science Education, in 1997.

Bob directed nearly 200 funded projects encompassing national and international work including Instructional Improvement Implementation Programs, Leadership Development Programs, Chautauqua Science in Professional Development Projects, and Salish Research Focusing on Science Teacher Education. Some of his national projects included Iowa Project ASSIST as a Mechanism for Curriculum Implementation, 1974-78; Honors Workshops for Teachers of Exemplary Science Programs funded by the National Science Foundation, 1984-90; An Iowa Chautauqua on Kit-Based Science, Title IIA Grant, Iowa Board of Regents, 2001; Changes in Classrooms Supported by Concerned Communities: Authentic Illustrations of Science Education Reform in Iowa, Annenberg/Corporation for Public Broadcasting, 1995-1997; National Diffusion Network Developer Demonstrator Program for both the Iowa Chautauqua Program, and the Iowa Scope, Sequence, and Coordination Project, 1982-95. Both projects were funded by NSF grants, 1982-2004 for transplanting Staff Development Projects in a dozen other states. Other key projects included Salish 1, 2 and 3 focused on Secondary Science and Mathematics Teacher Preparation Programs: Influences on New Teachers and Their Students, 1992-1997; and Physics, Earth Science, Chemistry (Korean Science Teachers), 1991-2008 and Iowa IMPPACT a study of science teacher education in collaboration with Syracuse University and North Carolina State, 2004-2010.

Bob's professional contributions are various and numerous. His mentoring of graduate students includes being a Chair for 130 Ph.D. Dissertations and Chair for 256 Masters student from 1958-2008. He was the director for Future Scientist of America from 1960-67 and the director and National Secretary, Association for the Education of Teachers of Science from 1961-70. Additionally, he was the director of the Iowa Science and Culture Project from the 1965-70; He served on the Editorial Review Board, National Association for Research in Science Teaching from the 1965-78. He served as president of several associations including: School Science and Mathematics Association, 1969-70; National Association of Biology Teachers, 1970-71; Association for the Education of Teachers in Science, 1973-74; Iowa Academy of Science, 1973-74; National Association for Research in Science Teaching, 1974-75; National Science Teachers Association, 1982-83; and International Association for Science, Technology and Society, 1992-93, 1996-99.

Other professional accomplishments included serving as director of research for the National Science Teachers Association from 1978-81; Director, NSTA-ERIC/SMEAC Study of Accomplishments and Needs of Science Education in the United States from 1979-81; Member, Executive Committee, National Science Teachers Association from 1980-84; Chair, Section Q, American Association for the Advancement of Science from 1981-84; Commissioner, Science Manpower Commission, American Association for the Advancement of Science from 1982-85; Associate, Center for Educational Competitiveness, Washington, DC from 1989-94; Member, Advisory Board, Scholastic SuperScience, National Science Foundation from 1989-1995; Member, Exemplary Science Materials, U.S. Department of Education from 1998-2000; and Member, Science Advisory Panel, Educational Resources Information Center (ERIC), 2004-present.

INTRODUCTION

We recently published an article, "A *conversation between Dana Zeidler, and Geeta Verma and Lisa Martin Hansen; Exploring further possibilities in science education*" in EURASIA *Journal of Mathematics, Science & Technology Education* to document Dr. Dana Zeidler's professional career and contributions. Such published pieces contribute to scholarly chronicling of prominent science educators and researchers. At a recent Association of Science Teacher Education (ASTE) meeting in Costa Mesa, California (2001), attendees were asked to stand if they had been a doctoral advisee and/or an 'academic grandchild' of Dr. Bob Yager. Over one-third of the attendees in the room stood up acknowledging the sheer number of scholars that were impacted by being a member of the academic lineage of Dr. Yager. Therefore, we felt that it would be of immense value to document and narrate Dr. Yager's personal and professional career and to note his contributions to the science education field. Re-constructing the history of the science education field through these personal interviews and other narrative approaches allow the readers to identify and examine the research issues, trends, themes, and directions in the science education field. In preparation for constructing this biographical narrative, we interviewed Dr. Yager at the 2008 International Conference of National Association of Research in Science Teaching (NARST) in Baltimore, Maryland.

Biographical Topics

We used the following biographical topics to illustrate the highlights of Dr. Yager's professional career. These topics emerged out of our audio- taped structured conversation with Dr. Yager. The biographical narrative includes our elucidation and construction of his professional events supported by verbatim quotations from Dr. Yager. The topics include:

- ✓ Dr. Yager's career
- ✓ Establishing science education at The University of Iowa
- ✓ The emergence of Science, Technology, and Society (STS) ideas
- ✓ Existing intersections between STS and Socioscientific Issues (SSI) ideas
- ✓ Reflections on working with doctoral students
- ✓ Considerations of the goals and aims for future directions for the field

Beginning of Dr. Yager's career

We asked Dr. Yager to describe his career path, indicating the nature of his ongoing engagement with the science education community. He started out by sharing the beginnings of his professional career, which eventually led him to science education. As he shared, "actually I have lived and been a professional teacher for much more than 60 years. But, I have been 50 years on the faculty at the University of Iowa. I did my graduate work all at the University of Iowa and so in a sense that was not all one stretch, because I have been teaching in Iowa [in 1950] after completing my Bachelor's degree and receiving a license to teach. I actually decided, unlike many people that I work with in teacher education, to be a teacher when I was in 7th grade. My mother was a teacher and I grew up on a farm in [Western] Iowa. She had gone off to then the Iowa State Teachers College, which is where I went to get my degree. Everyone in Iowa, if you [have] thought of teaching you would have actually thought of Cedar Falls [now the University of Northern Iowa]. [But, it is important to remember] that I was also very young when I graduated from high school".

Bob's elementary school didn't have kindergarten when he started first grade. When kindergarten was started, they split the first graders into two parts. Bob's Mother would not have him being in the first grade again – even though he "was among the youngest. My mother indicated that she did not want her son to repeat first grade". This all meant that he graduated from the high school a month after the age of seventeen. He was anxious to get his college degree and into teaching. He "graduated from my bachelor's degree by going a summer and a half, in 3 years. That together, I had my teaching certificate and I was ready for a job at the age of twenty". Bob minored in English where he enjoyed grammar and drama in high school. So here he was, "at age 20, teaching at a small town (Chapin, Iowa), teaching [students] biology, physics, and English [some of whom] were one year younger than me; the only thing that separated me from the students was, quite frankly, my dress. I never thought of ever going to school without a suit and a tie. And I did get messed up in the first year when they took pictures for the annual. All the kids came dressed up. It was rather embarrassing when the photographer stuck me in the middle of the row. I had to say 'just a minute. I am not one of the kids'".

"After my first year of teaching, I thought [immediately] of graduate school. At that point in time the University of Northern Iowa (UNI) had no graduate program; it was strictly an undergraduate place; so I had to find another institution. And I went with my father, across the state of Iowa, from western Iowa to eastern Iowa, and talked to the dean of the graduate college [at the University of Iowa], who happened to be a plant physiologist, about enrolling after one year of teaching in the graduate program. I was there just for the summer because I was going back to [my second year] of teaching... but interestingly, after my that first summer at Cedar Falls [at the University of Iowa] I had the faculty saying 'Why would you want to go back to teaching?' because I did so well in those first courses of graduate school. [I even was enticed to accept a teaching assistantship]. But, I did go back for year 2 at Chapin! However, after a second summer for my master's degree program, I decided to spend the next whole academic year with full time study and teaching at the U of I and completion of a Master's thesis. The Korean War was in full swing! I found myself being called (drafted) in the U.S. Army".

"I was a not a happy camper at the thought of carrying a gun, going abroad and shooting people!" Bob shared that, "I did serve and went through basic training and all that against my will. I was very thankful that my first orders included going to Germany rather than to Korea. I served two years in the army in Frankfurt, Germany. And my job, because I had my master's degree and had been a teacher, was actually to be a teacher at an [army education] center". Bob worked with army recruits who did not have a "4th grade equivalency". Bob shares, "so here I was teaching army recruits, who wanted to stay in the army and teaching them simple reading and math [skills] to at least at 4th grade equivalency or they would be released from the army. I was just anxious to get out of the army as soon as I could and to return [to PhD studies]".

Bob recognized the importance of this experience as he says, "in a way it was gaining special education preparation" on the job. This experience provided him with meaningful pedagogical experiences for adult learners with the methods being used to teach the recruits were very much "drill and practice". Bob recognized the importance of having people learn to think and conceptually understand versus simply reciting information and/or doing simple math drills with flash cards.

The army wanted him to stay on as a civilian and he considered it as he enjoyed Europe, especially the 3-day passes. After visiting over 18 different nations, which he says, gave him "very interesting insights", he was tempted to stay. However, he chose romance over a job offer and returned to Iowa to get married. They had dated while both he and his wife had been students at ISTC! He and his wife chose to live in Iowa City where his wife first taught at a nearby town: Washington, IA. Later his wife became the first diversity chairperson and "Family Living" instructor with the Iowa City public schools while completing M.A. and PhD degrees. Later she worked at Grant Wood Education Agency and headed diversity efforts there. That's the reason why following her fatal car accident, the University of Iowa sponsored and continues to sponsor a diversity conference in her name.

At the time, Bob applied for a PhD program at The University of Iowa. There was no science education PhD program. He was offered a teaching position in the biology department as a doctoral candidate. As he shared, "both of my graduate degrees are in Plant Physiology and have nothing whatever to do with education". His graduate studies for his Master's Degree focused on cell elongation of 'oat coleoptiles'. However, the more he thought about pursing this line of research (his advisor's specialty), he wondered, "Do I want to spend the rest of my life dealing with enzymes and what makes cells grow and elongate and all that sort of thing? It didn't appeal to me at all. [I decided teaching was more challenging and fun!] And, I enticed my advisor to move to another area of research – the chemistry of abscission. But, Bob also decided to talk to some of the College of Education administrators where he found great interest in his talents [but with no enticements to change his major]. I moved from the coleoptiles to tobacco plans in the greenhouse. I wanted to be, where there were other people around rather than in a dark room; I got very interested in floral abscission in tobacco plants. The idea was worth pursuing and got me to two sunny rooms in the greenhouse".

Establishing science education at The University of Iowa

While he was pursuing his Ph.D. in Plant Physiology, there was a vacancy at The University of Iowa Laboratory School. In the lab school all the department heads were the only permanent teachers. He had struck a chord with the director of the lab school. The science faculty had been depleted because there were no faculty members (3 over a ten year span) who had not achieved tenure. There were no remaining teachers and no one to chair the department. The lab school was used as a field setting for research in education and for practicum experiences for teacher education majors – and even student teaching. Not many publications were coming out of such a setting even in other departments with well known faculty department heads. The director of the lab school was struggling to employ people with a Ph.D. to both teach and conduct educational research. Therefore, Bob found himself working toward his Ph.D. in Physiology while also acting head of, "the science education program at The University of Iowa, in 1956 before I had my PhD. I was employed full-time without a PhD but in charge of a [science education] program with a master's degree [program and several students in progress]".

His teaching at the lab school impacted his views on college science teaching. As he shared his experiences in the lab school, "now getting back to the lab school experiences, it was such a rich place. Unique to our program was my tie to the sciences. Many of our early graduates [in science education were] really prepared to be college science teachers. I like to think mainly that I was one of the greatest contributors to that; you could be interested in teaching and teaching differently at the college level instead of just giving lectures and passing on. Bob enjoyed his experiences at the lab school as he had, "the luxury of having an idea that could be tried the next day". The science program was enlarged and at its peak there were ten PhD students who were faculty members in the science department. As he reflected on the intersection of pedagogy and intellectual engagement with students in the lab, he shared the paradox of doing experimental research with children could almost be interpreted as cruel to the children who were denied participation in any labs. In the lab school, they compared learning of students who only were given lectures and textbooks, others with only teacher demonstrations, a third section with many student-centered labs. It came as a shock to Bob that there were no differences on test performances. He shared his concerns about the ethics of education research in the lab school but he learned and shared his learning through publications.

The University of Iowa enticed T.R. Porter, a professor at Penn State University, to come to the University of Iowa to head the program in 1958. He was considered a national figure who could chart new pathways to excellence in science education. He wanted to head a Liberal Arts Core Service in the Basic Sciences, the elementary program that consisted of more than one methods course; he wanted a formal Center that was not simply part of the lab school or a facet of the College of Education. He wanted nothing to do with the lab school and/or the secondary teacher preparation program. Lastly he wanted Bob to stay on as a new assistant professor in charge of preparing secondary science programs and the science program in the lab school. T.R. Porter was instrumental in creating an entire graduate program focusing on science education per se. Bob explained the importance of this move to the university which gave T.R. Porter everything he wanted before accepting the new position at Iowa, i.e., over a full year of negotiation. "Science Education at The University of Iowa wouldn't be where it is today in science education without Porter's power to provide what he needed for developing an innovative program".

Over the years, Bob considered moving to other universities where he was offered faculty appointments. But, then he thought, " I guess there is no point in going to those [other places and starting new program features; he had already developed cooperative efforts across the whole state of Iowa]; and establishing working relationships with teachers and schools across the state. Every time I thought about it, I would say 'Look what I have got going here! I know the state! I know the university! I know the power of not having a degree in education! I know people who are willing to work with me! How long would it take to develop these kinds of relationships anyplace else?" T.R. Porter developed and established a Ph.D. in science education separate from the Curriculum and Instruction Ph.D. programs in the College of Education. At that time, Bob shared, "having a PhD program with nothing to do with the College of Education was a problem, in some ways -- interesting questions were raised over time -- a truly unprecedented action that lasted for several decades. Currently, science education is part of the Teaching and Learning Department within the College of Education at The University of Iowa. "How that happened and how it is working remains outside my control or knowledge base – especially with Emeritus Status".

The emergence of Science, Technology, and Society (STS) ideas

Bob's experiences in the lab school shaped his ideas about curriculum and student -centered learning. These experiences got him interested in STS ideas, which were originally proposed by other researchers in the field (Joe Piel from Stony Brook, Rustum Roy from Penn State, Janice Koch, Glen Aikenhead, Steve Cutcliffe). His ideas about STS were influenced by his experimental implementation of dozens of non-traditional curricula at the lab school. As he shared, "I am really fundamentally opposed to curriculum; [too often it is something to impose on teachers]. Even though I took the money [for field testing curricula] and probably directed over 150 NSF programs [to help teachers and schools to use them], I was enthralled with the efforts of the 60's [and how they promoted student learning]…and unfortunately, I think a lot of people want to return to that. I think it's an insult that you need a curriculum [developed by others] and applauded by others and the belief that you need a textbook. We have to [help] our students to see that is important to have something that they can refer to and I'd like to think... find problems with it... several researchers [have] done basically [that]; often times in chemistry & physics [texts] which are not my primary area [of expertise], where somebody can pick up a typical high school book and find 150 errors in it [The same is true for college science texts as well]! I am not smart enough to know the difference and obviously most teachers aren't; I really don't know [how] you can [experience and learn real science] with a [textbook]. I don't know why we pay them [textbook companies] money to try to [provide frameworks for courses and materials for teachers to use with students]".

One of the most enjoyable times during Bob's professional career was testing curriculum guides and materials. As he excitedly shares, "every new curriculum [that] comes out, we would [want to try it in the lab school and/or with teachers in professional development efforts]. The further it was away from tradition, the more we want[ed] to try it. So we really had not thought about doing anything that was completely open in different contexts. And, the turning point for that for me was work with the Project Synthesis effort. I think [many are] familiar with it. What *Research Says to Science Teachers*, Volume 3, from the National Science Teachers Association (NSTA) [provided reviews of relevant research that was designed to assist teachers]. [It was a great time] because at that point in time I was president of NSTA and work[ed] with Paul Hurd, Rodger Bybee, Jane Kahle on the Biology part of it... we shared, we pointed new directions, [and noted problems from the current research]. [Although I focused most on biology, my real fascination] was with STS, (Science, Technology, & Society) [which was identified primarily as -- an effort in U.K. and other European countries]. It [the STS effort for the synthesis research was] headed by Joe Piel from Stony Brook. There were several teams who had worked synthesizing the case studies [available research, and the 1977 National Assessment of Educational Progress]. "Joan Solomon [became a popular STS enthusiast] who is still alive and working; [she collaborated directly with many STS students and Glen Aikenhead, Canada]. Solomon's husband [is credited with] coining the name-STS (Ziman, 1980). I got very fascinated about what it means; what it could [look like], and what the current reforms [have in common]". Bob's interpretations and applications of STS ideas created much controversy in the science education field as other scholars in the field disagreed with him about the society emphasis and questioned the technology emphases in STS conversations. Often others did not approve of bringing in societal controversies into science programs. Bill Aldridge, the Executive Director of NSTA, would debate with Bob. He was willing to add technology, but seemed agitated and loudly proclaims that Society was not science!

Bob reflected on his understandings of the scientific enterprise and its connection with the STS ideas. He gives examples such as, Surely*, You're Joking, Mr. Feymann* and his ideas of what science is. He identifies the following: 1) Science is what scientists do to answer questions about the objects and events that characterize the natural world; 2) Science is also dealing with the explanations of the natural world that are not so; 3) Science is dealing with the things we do not even know that we do not know. Bob reported that he continues to use such ideas as those shared with Feymann. Bob continues by sharing that he feels that science is trying to respond to your own questions [not those of teachers or those included in textbooks!]. Scientists are doing that, I mean, and we tend to revere them [for it]. They [are seen as] knowing it all. Well, [shucks], they're not doing research if they already know the answer and they are sharing with you their previous answers. The bottom line is dealing with those things [we are curious about]. And I loved when AAAS Science journal came out with the 125 most significant things that we don't know [as part of] their 125th Birthday. Where [and how] do we deal with 'typical [unknowns],' especially if we got a text book [to follow]; if we got a state curriculum guide or whatever else with the things the student doesn't know – [but teachers and/or others want them to know]".

"John Dunkhase [a former Geologist who is a current science educator at Iowa] is one who was just this year going down the hall and looking very glum; I said 'John, what's wrong? You look so sad' and he said, 'I just found out today that two of the things that I knew yesterday, are wrong'! But how many times does that really happen? We even joke about that now. We have not begun to understand everything [about the objects and events] found in the whole universe. We don't even know how big it is and we miss the point of what science is". Bob felt that for most people science is the stuff in books, in courses, in curriculum guides all of which are labeled "science". Bob continued, "Teachers I think are too anxious to simply share what they know [while also working to look like they] can go further than the book". Bob lamented over the situation where we as teachers are too bound by standards, curriculum materials, and grade level expectations. He shared concerns of the science education community that teachers feel the pressure of needing to "cover" the curriculum, being accountable to various stakeholders, and creating learning experiences that are often shallow for deeper understandings due to these constraints. He reflected on his experiences as a research scientist, "I got very fascinated with it... I love plants and trying to understand how they grow. The thought was [initially that], I could be in the lab school and could still keep up with some abscission research. I have 12 or 15 [publications] in the most prestigious journal of plant physiology". His work in the lab school was innovative and exciting in his professional career where he could 'experiment' with new ideas similar to his experiences in doing research in Botany. He was able to coalesce the idea of "teacher as researcher" promoted by NSTA since he himself played that dual role in the lab school. He criticized teachers who make excuses for not attempting innovating ideas on their own -- they do not view their teaching as something from which they can learn. If every teacher would work on one problem a year or a month (or every day), we would have a revolution! Bob recognized the challenges placed upon the teachers by the federal and state guidelines and the feeling that they must do what they are told! But, they do not have to do it smiling!

He expounded on the implementation of STS workshops including his Chautauqua efforts beginning in 1983 -- and emphasized that he doesn't consider them to be "his workshops" because "[we started with] from the very first one, it was the idea of teachers helping [other] teachers [and] not being prescriptive but [instead] opening opportunities". An example of a teacher who embraced the ideas of exploring STS was a woman from Davenport, Iowa, who later became the editor of *Science and Children*. Joan McShane conducted many investigations with STS approaches including tooth brushing and toilet flushing. Her science students enthusiastically investigated scientific ideas guided by STS to the extent that she became famous in the Quad cities where she was known as the "Flush Queen". As Bob shared, "Joan was able to get her students to investigate science phenomena all over town [and] emphasize [how] local issues such as water pollution [and other environmental issues indicated real problems on which students can work]".

Another example is of a teacher who attended STS workshops who realized that several students in his class were interested in becoming hair stylists. This teacher shared with Bob that one of his students initiated questions about ozone depletion as a result of their interest in hair styling products such as aerosols. This group of academically low-performing students got so interested in the topic that they wanted to explore deeper investigations for the rest of the year. In essence, all the information in the standard text was needed – but for a purpose other than being the next chapter to "go over"! The students at that time enrolled in the college preparation sections complained about doing just worksheets and wondered why the low-performing students got to do the fun activities.

"[Many people] didn't understand what many of us are trying to do 'how we define STS?' and many people have, in my opinion, defined it wrongly. They are just adding chapters to the book dealing with some issues. The issue doesn't become the organizer for the course. I would say the people [who] say that they are doing STS with the textbook or that they have a unit at the end; it is [just] a 'tack on' thing. They are missing the point even though they claim to be STS [enthusiasts]! They are missing the point of its [real] value [as an invitation to thinking and learning] ". The examples of how in Bob's views cast STS as an educational philosophy and an approach to teaching are important and indicate the problem of "their being add-ons to an existing curriculum. STS affects teaching more than influencing the curriculum. How teachers teach is more important than what they choose to teach".

Existing intersection between STS and Socioscientific Issues (SSI) ideas

We sought Dr. Yager's opinions about the existing intersection of STS and the emerging SSI conversations in the field. He responded, "I think it's fine. My bias is that we [in the STS community] have been interested in that... in fact being interested in social issues, is what turned a lot of [many] people [off] initially. As a matter of fact, they said that 'you are not teaching science unless you have a physics course and so we were criticized for being too far out. Now some of these people, having written articles on 'Beyond STS' [encourage us] to go beyond; it is almost like [when] Ron Good wrote an article against STS because it had nothing to do with learning theory and constructivist practices. So, we responded to that in a whole SUNY Monograph (STS as a Reform in Science Education). Martha Lutz wrote one chapter in the monograph which she stated that 'you don't understand STS'; that's [when someone says] 'Let's go beyond. I am willing to go beyond it"'. But, what do you think it is?

"And, there is nothing wrong with taking that little step with your moral values and socio-cultural [values], and ethics… I think the problem is [that] many people view STS in a curricular sense only. To me, the far greater way of looking at STS is a new way of teaching. I like to say that is why the teaching standards are first in the standards because [they are] the most important aspect of the needed reforms. 'Do what you do as a teacher' in a different way than just transmitting the information or following the curriculum or whatever else. Again, I don't have any quarrel with any [one] moving into this social/cultural area. I say ideally STS people should be doing that. Joan McShane [Davenport, Iowa] was doing that. Jim Coleman was doing it in Denison, Iowa. And, in their minds they view STS [as going] a little too far with it…And, [as mentioned earlier], Bill Aldridge went nuts with the word 'society'."

Bob expressed that in terms of societal and technological aspects of STS many people have difficulty understanding how these aspects relate to the science found in textbooks and curriculum frameworks. He believes that we haven't been specific enough in our definitions of these key terms and ideas. As he shares, "the terms in and of themselves don't have meaning – [meaning must first be established among the discussants]…I always have to keep [this] in mind that [perhaps it is only my interpretation]. God has not specified [his/her definition on us as some die-hards continue to search for the 'real' meaning of a term like inquiry]. [It seems to me] that we [must remember that we humans give] them [words] meaning. And, I guess in terms of these kinds of conflicts, I would say we haven't specified enough [i.e., meaning-making]. I don't know how many people really deal with the term 'Science' or 'Technology"'. He argued that science educators (both university and at the k-12 level) don't have much preparation in the "sociology of science, history of science, philosophy of science, and/or economics of science". He elaborated, "many of these people assume right up front that when you say science [that] you mean understanding rocks better or knowing what [a] living system is or whatever else; there remains much disagreement! Again, I think most linguistics experts agree that no term has any meaning until meaning is first established. And so, it's our fault that we have not been able to delineate very well".

Bob began discussing how many people including scientists agree that, "science is an exploration/explanation of the material universe seeking explanations for their objects [and events encountered]. So that means [that] anything that you encounter, objects [in and/or around the earth] almost cover everything and I sometimes jokingly, too say, it just leaves out heaven and hell and places we haven't [encountered] yet. We don't even know that they even exist at the edge of the universe. And, then with the [term] technology, one of my bones of contention is that too many people who when dealing with the design world think only of computers...we [build] bridges and [this brings] engineers into [the picture]. I think we were dead wrong in the 60's saying 'leave out the technology [in texts and curricula, it is NOT Science]'. Now we are saying it is 'science and technology'. Of course, I think that's the reason I don't even like the [term] STS because with science and technology [being] up front... and a lot of the people ignore one or the other. I like [including] 'society' because science involves people and their brain[s] at work and people working with each other or fighting each other. All these are ways that we increase [understanding of] where we are going [and provides real experiences with the essence of science]".

Reflections on work with doctoral students

Bob has worked as the chair for 130 Ph.D. dissertation committees and 256 Master committee in his prolific career at The University of Iowa. He has helped form one of the most active programs in science education. He shared the long history of the Ph.D. program saying that, "our program changed over the years, as well. Many of the early [graduates] were on the science faculty at UNI; many [others] went to colleges [and K-12 schools as science teachers]. I am proud of that, although frankly, people like Fletcher Watson at Harvard criticized [me] for that...because science education leaders at NARST were meant to prepare teacher [researchers]…and here was a large program in Iowa that was preparing people who weren't going to be primarily science education researchers. But you see, I don't like to separate science education research from action research by teachers or whatever. I think the mind should [ask] questions and [that we] should be dealing with them".

Having worked with numerous Ph.D. students, Bob offered advice to doctoral students in the field. First and foremost, he believes that doctoral students need to be curious; secondly, it is highly advisable for them to become a part of a research team during their doctoral studies. Additionally, he recommends that doctoral students seek out a faculty member who is in the same research field in which a student has an interest. However, he cautions doctoral students about working with faculty who may not be open to diverse research methodologies and findings. For example, he shared a story of a Ph.D. student who worked closely with a faculty member on the faculty's line of research in microbiology with two other graduate students. The dissertation topic was assigned to this student and after two years of doing research, the student just gave up as the faculty member disagreed with the findings. Bob strongly advocates that both students and faculty must have open minds and to allow students to explore their research interests within a broad framework of faculty expertise. For future doctoral students seeking an entry into the field, he recommends exploring a broad research line of inquiry and guarding against being pigeonholed by faculty into a very narrow and confining focus.

Considerations of the goals and aims for future directions for the field

In reflecting on his association with the science education community, Bob shared a bit of history of a professional organization such as NARST. He shared, "as I see NARST is an organization [now] and fifty years ago where it was like a fraternity, [i.e., a small prestigious group]. I mean, you were invited to join NARST! One of the first things that T.R. Porter did was try to get me into [NARST]. Even as late as 1970's or 1980's, there were only 35 institutions in the U.S. that had a Doctoral program [in science education] with more than 5 students". Thereby, Bob felt that The University of Iowa had prominence because of the 12 faculty members in science education all with varied interests, expertise, and involvement outside of Iowa. Bob described 'the fight over' research journals in the science education field. He recalled, "JRST as being relatively new, mainly because the old one *Science Education* was an early editor's 'property'… After, the death of this long time editor, his wife sold the journal to a publishing company who continues to appoint editors to accomplish the needed focus on valid research to make the journal competitive. Now it is a competing journal to the NARST publication, *Journal of Research in Science Teaching* with the same publisher [Wiley-Blackwell]". Bob recalled about the growth of the journals in science education by sharing that *Science Education* and *Journal of Research in Science Teaching* have been serving science education researchers. Both journals have undergone many changes and each has matured and has become more professional.

When asked about his joys and struggles, Bob described the ongoing struggle of the identity of the science education program at The University of Iowa, including the program becoming an integral part of the new department of teaching and learning of the College of Education. This is opposed to its being an independent entity among the science department with a long time PhD in the Graduate College. In terms of his joys, he shared that he is enjoying his retirement and opportunities for travel outside the US for work related collaboration including places such as Estonia, Korea, Turkey, Taiwan, and Thailand.

As he reflected on the future of the science education field, Bob shared, "the future is bright" although he is "very concerned that most of the state [science] standards actually do negate the national [science] standards. The national standards 'didn't come from God' but he feels good about the quality of the national standards as so much time and money and hard work went into the development of them. Although, Bob recognizes the importance of reform documents, he shares his deep concerns with other policies such as 'No Child left Behind' as the implementation of these policies seem to now focus on teachers as factory workers. Teachers are individually being held accountable for their students' performances on external tests with no ties to what visions for reform are like. Instead teachers are forced to teach from the text and not consider the needs and interests of their students. Bob strongly felt that, "there is no real collaboration" to solve these educational challenges. As he emphasized, "collaboration is the highest part of the education pyramid. True collaboration means everybody involved equally; not somebody on top telling other people what to do. And, the teacher in a building is often times a person, fighting the other departments, wanting more time". He argued that if we continue to operate this way, then, 'we are not a profession"'. He would like to see NARST as an organization reaching out more than it does, "we all need each other. The good is again that nobody is against education. Nobody is against teaching and [nobody is against learning]. But, what are our common goals? What are we after [with regards to more scientifically literate graduates]?...I don't see many people debating [these efforts and then discussing what evidences we can provide for their validity]. So many people think that they know the answer already".

Concluding thoughts

We recognize that we have only touched upon Dr. Yager's contributions to the field of science education. Hopefully, this article will enable members of the science education community to get a sense of his scholarly contributions and impact on the field.

Appendix: Selected Publications, Robert Yager

Referred Journal Articles

Yager, R. E. (2009). Research in the Classroom: Student Learning about Twelve Features of the Nature of Science. *School Science and Mathematics, 101* (1), 57-61.

Kaya, O. N., Yager, R., Dogan, A. (2008). Changes in Attitudes Toward Science-Technology-Society of Pre-service Science Teachers. *Research in Science Education.* On-line only: DOI 10.1007/s11165-008-9084y.

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Books

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