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Factors Influencing Teachers' Use of Technology and PBL in Middle School Science Classrooms

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The purpose of this study is to examine middle school teachers' use of technology and problem-based learning (PBL) in their teaching practice. Factors related to teachers' use of technology and PBL are also investigated including: teachers' computer and Internet skills, feelings of preparedness to use the Internet, attitudes toward the use of web resources, pedagogical beliefs, science teaching efficacy, and the use of general teaching strategies. Twenty-seven middle school science, math, and technology teachers participated in the study. Research results describe the participants as slightly proficient in computer and Internet skills, positive toward use of web resources, and neutral on feelings of preparedness toward use of computer and the Internet. Participants also tended toward constructivist pedagogical beliefs and used various teaching strategies. They, however, reported low science teaching efficacy. Teachers' use of computers and the Internet correlated with pedagogical beliefs and feelings of preparedness toward the use of computers and the Internet. The study also found the relationships between the use of PBL and teachers' computer and internet skills, pedagogical beliefs, and the use of general teaching strategies. Also discussed are meaningful implications for teachers' professional development, especially for the programs designed to facilitate the use of web-enhanced PBL.

Keywords : technology use, professional development, teaching methods, teacher characteristics, problem-based learning(PBL)

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Introduction

The pedagogical trend toward constructivist approaches for teaching has gradually changed the science classroom, as Reeves' earlier case made clear (1993). The movement is from a more instructivist classroom where the learner is a passive recipient of information to a more constructivist one where knowledge building is a learner-centered process. Problem-based Learning (PBL), one of the teaching and learning methods which share some key assumptions with constructivism, has been strongly supported as a powerful and effective approach to science teaching (Taconis et al., 2001). In a PBL environment, students are able to develop deeper understanding of content knowledge as well as improve their problem-solving skills by situating themselves in real world problem-solving contexts (Edens, 2000; Lovett, 2002; Voss, 1989), where technology plays a role as an enabler.

Teachers and students have been using a variety of technology within the PBL classroom, and the technology varies from the blackboard in the study of Hmelo-Silver (2004) to the Interactive Case-based Online Network in the Harvard Medical school (Nathoo et al., 2005). Considering that the essentials of PBL are authenticity, resource-rich environment, and collaboration (Barrows, 1998; Hmelo-Silver, 2004), teachers naturally use technology often in the PBL environment, in which, for example, the authenticity of the problem scenario can be enhanced by using real images, sound, or movies. Web-technology supports students' access, selection, analysis, and storage of resources to solve problems. In addition, students can communicate, not only asynchronously but also synchronously via wired or wireless networks using text to video conferencing (Uden & Beaumont, 2006). With the arrival of the Internet, exciting possibilities exist for delivering science curriculum, enriched by powerful new technologies (Cuthbert & Slotta, 2004; Linn, 1995).

According to the report from the National Center for Education Statistics (2006), the integration of computer and Internet-based technology as a delivery method and the PBL model as a pedagogy in middle school science classrooms sounds feasible, from the view point of availability of technology: 94 percent of the instructional

rooms in public schools in the United States had access to the Internet in the fall of 2005. More importantly, the ratio of students to instructional computers with Internet access in public schools was 3.8 to 1 in 2005.

However, the real story is not that simple. Although access to computers and the Internet at the school-level has rapidly increased, little data is available on teachers' actual use of technology in their classrooms (National Center for Education Statistics, 2005). Cuban (2001) also argued that computers have been "oversold" for restructuring the educational environment but generally are "underused" for regular classroom instructional practices. The explanation for "under use" is two fold: the lack of teacher training to use educational technology and the lack of instructional strategies for integrating technology into the curriculum (National Center for Education Statistics, 2000), both of which relate to teachers. Although teachers are the people who actually integrate technological and pedagogical advances seamlessly into their teaching practice, researchers have focused more on students' achievement gains resulting from innovations, not on the teachers who have implemented them. Considering that the ability of teachers is the major determinant for the quality and the success of PBL (Barrows, 1992) and other types of instruction as well, obtaining a better understanding of teachers and their roles by examining who they are and what they do in the classroom is essential.

This study examined how middle school science teachers use technology, specifically computers and the Internet, and PBL in their classroom. Teachers' use of computers and the Internet is defined as the ways that teachers use computers and the Internet for teaching or other professional activities. Across a substantial body of research, the use of computer-based technologies encompasses emailing, maintaining records, preparing and delivering instruction, and directing students' use of technology (Russell et al., 2003). This study categorized the use of technologies as: 1) teacher activities including emailing and preparing and delivering instruction, and 2) student activities directed by the teachers. The use of technology for student activities is important in PBL. It is the extent to which teachers use teaching strategies and techniques related to PBL, including providing a problem as a learning task,

encouraging collaboration, and developing critical thinking.

An extensive literature review assisted identifying tentative factors that may influence the use of technology and PBL. Among these are factors of teachers' characteristics and instructional practice. As a result, six major variables emerged: 1) teachers' computer and Internet skills, 2) feelings of preparedness to use the Internet, 3) attitude toward the use of web resources, 4) pedagogical beliefs, 5) science teaching efficacy, and 6) the use of general teaching strategies. These variables are believed to influence science teaching practice on two levels: technology use (in this study, use of computers and the Internet in the classroom) and the use of a particular instructional strategy (in this study, PBL method).

Computer and Internet skills refer to teachers' knowledge and skills for using computers and the Internet for their teaching. Becker (2001) found that teachers' levels of technical expertise affects the ways they have their students use computers in the classroom and their own use of the Internet as a valued educational resource (Becker, 1999, 2001).

Another important factor that affects teachers' levels of technology implementation is teachers' attitude as well as their feelings of preparedness toward using computers and the Internet (Becker, 1994; Bigatel, 2004). For many instructional activities, teachers who reported feeling well prepared to use technology would be more likely to use it than teachers who indicated that they felt unprepared (Parsad et al., 2001). Teachers' beliefs and attitudes about technology might not be always consistent with how comfortable teachers actually are with using technology in the classroom. A Teaching, Learning, and Computing survey found that nearly 90 percent of teachers consider the Internet a valuable resource (Becker, 2001). On the other hand, the data collected by the National Center for Education Statistics (1999) showed that fewer teachers feel prepared to use technology.

While technical skills remain one of the most important variables in teachers' use of computers and the Internet, what teachers believe to be good instructional practices also affects the ways teachers use these resources in their classrooms. Becker (1999) found that teachers' pedagogical beliefs are one of the major predictors of

teachers' Internet use and valuation. Pedagogical beliefs are teachers' beliefs concerning what they see as good instructional practice. Teachers' beliefs of what constitutes good teaching reflect their understanding of how students learn (Ravitz et al., 2000). Other research showed that most teachers when asked about the relationship between their pedagogical beliefs and their teaching practice reported having a balanced combination of traditional and constructivist approaches in their classrooms (Becker, 1999). Riel & Becker (2000) investigated the relationship between teachers' beliefs, teaching practices, and computer use. They found that instructional leaders, i.e. teachers actively involved in professional development, were more likely to use constructivist pedagogy and computers in their teaching practices.

Use of general teaching strategies are the frequencies with which teachers use a variety of classroom teaching strategies and techniques, such as questioning, examples, small groups, concept maps, and the choice of these strategies. How often teachers use different teaching strategies and their selection of strategies may have strong implications for teachers' use of and attitudes toward web-enhanced PBL in middle school science education. Research shows that variables such as technical skills, attitude toward technology, constructivist teaching strategies, and constructivist teaching philosophy all influence constructivist uses of technology (Kirby et al., 2003).

Science teaching efficacy impacts teachers' belief systems and their sense of confidence as it relates to their ability to be successful teachers (Tschannen-Moran et al., 1998). Science teaching efficacy reflects personal judgment about one's ability and competence to perform tasks related to teaching science. Efficacy influences choices of activities as well as the amount of effort expended and the level of persistence in the face of obstacles (Wingfield et al., 2000). Research has shown correlations between science teaching efficacy and various measures of teacher effectiveness, including classroom behaviors, attitudes, and commitment (Evans & Tribble, 1986).

Even though substantial science education literature considers many variables of teachers' characteristics or teaching practice, currently, no coherent framework or model explains the complicated interrelationship among teacher or teaching-related

variables and teachers' use of technology and PBL. Accordingly, the research questions of this study are 1) how do teachers use computer/Internet technologies and PBL methods in their classroom? And 2) among teachers' characteristics—computer and Internet skills, attitudes toward the use of web resources, teachers' feelings of preparedness to use computers and the Internet, pedagogical beliefs toward PBL, use of general teaching strategies, and teachers' science teaching efficacy, which factors relate to the teachers' use of computer/Internet technologies and PBL methods? The second research question is visualized as Figure 1, based on the findings from the literature mentioned earlier. Figure 1 also suggests a model that represents connections between teachers' characteristics and teaching practices.

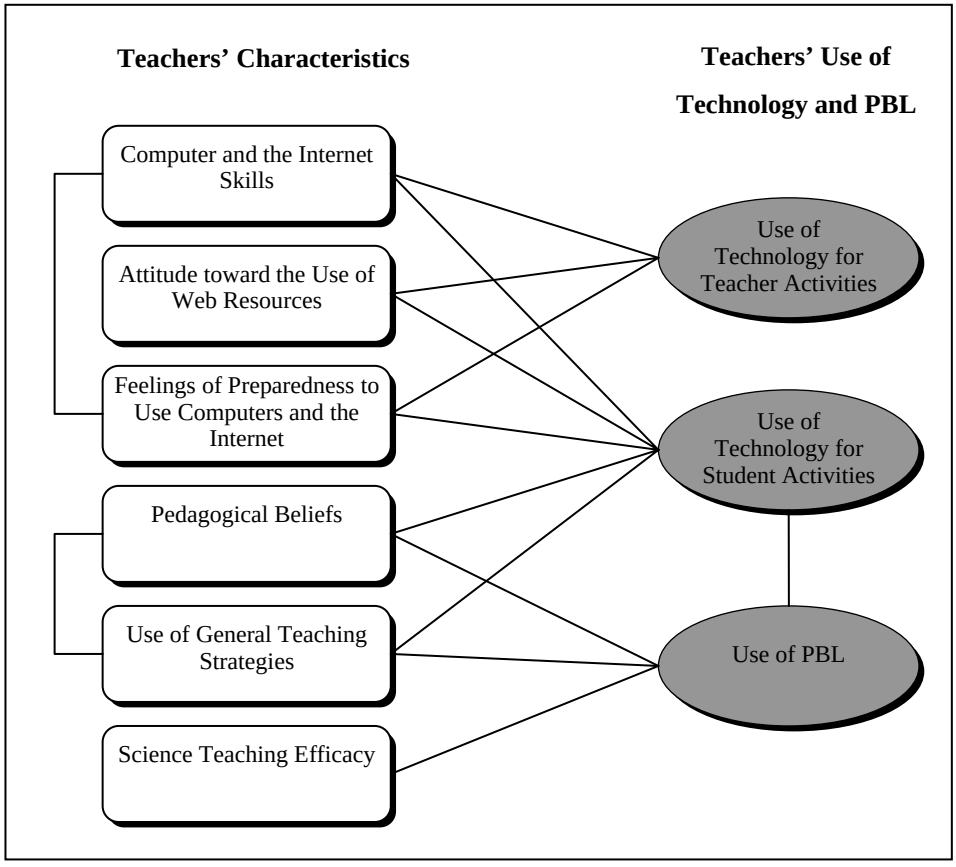


Figure 1. Tentative model of teachers' characteristics and teachers' use of technology and PBL

Methodology

Participants

To participate, teachers, recruited through one eastern NASA Space Grant Office and multiple listserves for science teachers, needed to satisfy the following criteria: currently teaching fourth through eight grade science, math, technology or geography, having computers and Internet access available in their classrooms or schools, and being interested in teaching at least two lessons using KaAMS (Kids as Airborne Mission Scientists, a website that provides PBL lesson plans and teaching resources for middle school science teachers). Participants were twenty-seven middle school science, math, and technology teachers (9 males and 18 females; 22 science teachers, 1 math teacher, 1 home school teacher and 3 technology teachers). Most were from different middle schools in the northeast United States (8 eighth grade teachers, 9 seventh grade teachers, 9 sixth grade teachers, and 1 fifth grade teacher). Participating teachers could choose one of the following incentives: a NASA polo shirt or a videotape/CD-ROM on Earth Science produced by NASA.

Procedure and Analysis

The participating teachers took eight online surveys that measured different characteristics and teaching practices regarding the use of technology and PBL. After reading and agreeing to an online informed consent form, teachers registered online to create their own login ID and password before continuing with the online surveys. Most teachers completed the surveys within a few days. The surveys required approximately two hours to complete, and multiple sessions for completion were acceptable.

Measurement Instruments

Several instruments, used or adapted from a variety of existing instruments,

provided data. Table 1 presents the original sources, number of items implemented, and Cronbach's alpha calculated after modification to suit the research context. A reliability analysis for each instrument shows strong internal consistency among responses.

Table 1. List of Measurement Instruments

Variables	Cronbach's Alpha	# of items	Source*
1. Computer and the Internet Skills	.945	15	Koszalka (2000) (M), Becker and Anderson (1998) (M)
2. Attitude toward the Use of Web Resources	.932	24	Koszalka (2000) (M), Becker and Anderson (1998) (M)
3. Feelings of Preparedness to Use Computers and the Internet	.870	2	U.S. Department of Education (1999) (M)
4. Pedagogical Beliefs	.710	26	Becker and Anderson (1998) (U)
5. Science Teaching Efficacy	.844	25	Riggs and Enochs (1990) (U)
6. Use of General Teaching Strategies	.736	12	Grabowski, Koszalka, and McCarthy (1998) (D)
7. Use of Computers and the Internet	.871	22	Becker and Anderson (1998) (U)
8. Use of Problem Based Learning	.889	12	Grabowski, Koszalka, and McCarthy (1998) (D)

* M: Modified from source, D: Developed based on source, U: Used from source

Computer and the Internet Skills

This instrument includes 15 questions: eight questions on teachers' skills for integrating different web-based resources into their lessons, adapted from Koszalka (2000) and nine questions on teachers' skills for performing various tasks, adapted from Becker and Anderson (1998), for using computers and the Internet. The stem for the first part is: "I have the skills to integrate…" This stem is completed by phrases such as: "informational web resources such as narratives, graphics, or pictures

in my lessons." The stem for the second part is "I have the skill to…" which is completed by phrases such as: "create documents using word processing software (e.g., Microsoft Word)." The responses to questions are via a 5-point high skill/low skill scale. Some questions, modified from the ones in the original source, allowed better matching with the measurement purpose in this study. The score for this instrument is the average item score, ranging from 1 to 5. Low scores indicate low levels of computer and Internet skills and high scores indicate high levels of computer and Internet skills.

Attitude toward the Use of Web Resource

This 22-item instrument measures teachers' attitudes toward the use of web resources. Specifically, the three-part instrument measures teachers' intention to incorporate different web-based resources into their lessons, teachers' opinions of incorporating the different web-based resources into their lessons, and positive/negative perception of using web resources in the classroom. The items, adapted from Koszalka (2000) and Becker and Anderson (1998), use a 5 point scale. Sample statements are: "I have a plan to incorporate information web sites such as current and historical events, descriptions, databanks, or advertisements into lessons I create in the future." And, "Effectively incorporating web resources into lessons can enhance instruction." The score for this instrument is the average item score, ranging from 1 to 5. The higher the score a teacher has, the more positive the attitude the teacher has toward the use of web resources.

Feelings of Preparedness to Use Computers and the Internet

This instrument has two questions, adapted from the survey on Public School Teachers' Use of Computers and the Internet developed by U. S. Department of Education (National Center for Education Statistics, 1999). The questions score on a 4-point Likert-type scale. The score for this instrument is the average item score, ranging from 1 to 4. A teacher with a higher score feels more prepared to use

computers and the Internet than a teacher with a lower score. The questions are: "In your opinion, how well prepared are you to use computers for classroom instruction?" And, "In your opinion, how well prepared are you to use the Internet for classroom instruction?"

Pedagogical Beliefs

This instrument measures teachers' perceptions of their pedagogical beliefs. It includes five sub-parts with 26 questions taken from Becker and Anderson (1998). Specifically, the instrument covers teachers' opinions about different types of class activity (instructivist vs constructivist), teaching philosophies, and the usefulness of different assessment methods. The score for this instrument is the average item score, ranging from 1 to 5. A high score indicates pedagogical beliefs geared more toward constructivism and a low score indicates pedagogical beliefs geared more toward instructivism or direct teaching. Sample statements about pedagogical beliefs are: "Instruction should be built around problems with clear, correct answers, and around ideas that most students can grasp quickly." And, "Teachers know a lot more than students; they shouldn't let students muddle around when they can just explain the answers directly."

Science Teaching Efficacy. This instrument

developed by Riggs and Enochs (1990), measures self-efficacy for teaching science. It uses a 5-point Agree/Disagree Likert scale with 25 items. The score for this instrument is the average item score, ranging from 1 to 5. The higher the score a teacher achieves the higher their science teaching efficacy is. This instrument includes statements such as "Even when I try very hard, I don't teach science as well as I do most subjects." And, "I generally teach science ineffectively."

Use of General Teaching Strategies

Twelve questions constitute this instrument, which measures teachers' frequency

of using various teaching strategies found in Grabowski, Koszalka, and McCarthy (1998). It scores on a 3-point scale: never, occasionally, often. The higher the score a teacher achieves, the greater the variety of teaching strategies a teacher uses. Examples of general teaching strategies used in this instrument are: "using a questioning, conversational strategy and expecting students to respond," "presenting the rules using pictures, context and prerequisite information," and "using activities that help students create organizational relationships among concepts."

Use of Computers and the Internet

The intent of this instrument is to measure teachers' use of computers and the Internet for teacher-related activities and student-related activities. The instrument, taken from Becker and Anderson (1998), has 22 questions divided into 2 sub-scales. The first sub-scale includes the first 10 questions, identifying the activities that teachers have students with computers such as: "mastering skills just taught," "finding out about ideas and information," and "analyzing information." These are yes/no questions. The score of this sub-scale (ranging from 0 to 10) is the result of summing the scores for all items. The higher the score, the more activities teachers have students do with computers. The second sub-scale includes the last 12 questions which measure the frequency with which teachers use computers and the Internet in preparing for teaching classes or in other professional activities such as "writing lesson plans or related notes," "reporting or calculating students grades," and "accessing research and best practices for teaching." Similar to the student activity section, the questions are yes/no questions, and the score of this sub-scale (ranging from 0 to 12) is the result of summing the scores of all items. The higher score means that teachers frequently use computers and the Internet for their activities.

Use of Problem Based Learning

This instrument measures the frequency of teachers' use of various teaching strategies that support PBL. These strategies can be found in Grabowski, Koszalka,

and McCarthy (1998). Sample strategies are: "I provide a real problem for students to solve when they are learning various topics." And, "When my students solve a problem, I facilitate and coach." Twelve questions constitute this instrument which uses a 3-point scale: never, occasionally, often. The score for this instrument is the average item score, ranging from 1 to 3. A high score indicates more frequent use of teaching strategies that support PBL.

Results

Descriptive Results

Table 2 presents descriptive results for each variable of interest from the twenty-seven middle school teachers. Participants reported their computer and Internet skill levels as slightly high (m=3.43; SD=.85). The attitude toward the use of web resources was reported as highly positive (m=4.14; SD=.62), which shows participants' positive attitudes toward incorporating web resources into their classrooms. On the other hand, feelings of preparedness toward the use of computers and the Internet is reportedly neutral; neither high nor low (m=3.15; SD=.77). Regarding teachers' pedagogical beliefs, results show that participants have slightly more constructivist than instructivist beliefs (m= 3.67; SD=.36). However, teachers' science teaching efficacy was somewhat low (m=2.05; SD=.40). Finally, teachers reported they used a variety of teaching strategies rather than only one or two strategies.

Regarding teachers' technology use, which is one of the major constructs of interest in this study, the results show that the intended purposes for teachers' technology use for student activities varies a lot. On average, any given teacher directs students to use computers and the Internet for seven to eight different purposes such as communication, collaborative work, or analysis of information (m=7.5; SD=2.12).

Among 10 activities suggested in the survey, 100% the participants reported that their students were using computers and the Internet for "finding out information and ideas" (see Table 3).

Table 2. Means and Standard Deviations of the Survey Result

Variables	Mean	SD	Scale
1. Computer and the Internet Skills	3.43	.85	Likert (1-5)
2. Attitude toward the Use of Web Resources	4.14	.62	Likert (1-5)
3. Feelings of Preparedness toward the Use of Computer and the Internet	3.15	.77	Likert (1-4)
4. Pedagogical Beliefs	3.67	.36	Likert (1-5)
5. Science Teaching Efficacy	2.05	.40	Likert (1-5)
6. Use of General Teaching Strategies	2.64	.23	Likert (1-3)
7-1. Use of Computers and the Internet for student activities	7.50	2.12	Interval (1-10)
7-2. Use of Computers and the Internet for teacher activities	9.62	2.26	Interval (1-12)
8. Actual Use of Problem Based Learning	2.48	.34	Likert (1-3)

Table 3. Purposes of Using Technology for Student Activities

I have used computer and Internet to have students…	% of Teachers who use the activity
1. Find out ideas and information	100.0
2. Improve computer skills	91.3
3. Learn to work independently	88.5
4. Express themselves in writing	84.6
5. Remediate skills not learned well	80.8
6. Master skills just taught.	73.1
7. Learn to work collaboratively	69.2
8. Analyze information	65.4
9. Present information to an audience	61.5
10. Communicate electronically with other people	34.6

According to Table 2, teachers themselves used technology for a variety of purposes. On average, any given teacher used computers and the Internet for more than 9 different activities of the 12 given (m=9.62; SD=2.26). The most frequently used activities were for obtaining information from the Internet and communicating with colleagues and/or other professionals (see Table 4).

Table 4. Purposes of Using Technology for Teacher Activities

I have used computer and Internet to …	% of Teachers who use the activity
1. Get information from the Internet for class	100.0
2. Communicate with colleagues/other professionals	100.0
3. Create instructional materials (i.e., handouts)	96.2
4. Write lesson plans or related notes	88.5
5. Record or calculate students grades	88.5
6. Make multimedia presentations for class	88.5
7. Communicate with students' parents	79.6
8. Exchange computer files with other teachers	73.1
9. Use camcorders, digital cameras, or scanners to prepare for class	69.2
10. Access research and best practices for teaching	69.2
11. Communicate with students outside the classroom/classroom hours	50.0
12. Post student work, suggestions for resources, or ideas and opinions on the World Wide Web	34.6

The participants reported that they use PBL strategies quite often (m=2.48; SD=.34). Most notable was that all of the items scored above 2 (see Table 5), which means that each strategy has been employed at least "occasionally."

Table 5. Use of Problem-based Learning Strategies

How often do you use following teaching strategies?	Mean (1=never, 3=often)
1. Collaboration is encouraged among my students.	2.81
2. I try to present complex situations in a realistic environment.	2.70
3. When my students solve a problem, I facilitate and coach.	2.67
4. I provide a real problem for students to solve when they are learning various topics.	2.63
5. My students identify with the problems I present and become actively involved in generating a solution.	2.58
6. Students are in the role of an active participant in a realistic task or event.	2.52
7. I use an authentic, performance-based assessment as a seamless part of my instruction.	2.48
8. I give my students guidelines on how to approach problems, not specific directions to solve problems.	2.41
9. Problems usually drive my lessons.	2.33
10. I present problems for which multiple solutions are possible, depending on student's perspective and data provided.	2.30
11. My students actively manipulate and explore case data.	2.26
12. I present a problem in a narrative format or story with embedded data.	2.04

Correlational Results

The variables related to the Use of Technology

As predicted in the tentative model based on the literature review, teachers' computer and the Internet skills significantly correlated with the use of computers and the Internet (for teacher activities $r=.691$; $p<.01$; for student activities $r=.408$; $p<.05$). Teachers' pedagogical beliefs significantly related to the use of the computer for teacher activities ($r=.429$; $p<.05$). That is, teachers who believe in constructivist approaches tended to use technology more often. Feelings of preparedness toward the use of computers and the Internet is another factor that significantly related to the use of computers and the Internet for teacher activities ($r=.454$; $p<.05$). At the same

time, no significant correlation appeared for the use of computers and the Internet for student activities (r=.192; p=.347).

Table 6. A Summary of Correlations between Variables

Variables	1	2	3	4	5	6	7-1	7-2	8
1. Computer and the Internet Skills	1								
2. Attitude toward the Use of Web Resources	.297	1							
3. Preparedness toward the Use of Comp. and Internet	.662**	.216	1						
4. Pedagogical Beliefs	.406*	.190	.205	1					
5. Science Teaching Efficacy	-.040	-.572**	.035	-.013	1				
6. Use of General Teaching Strategies	.174	.129	.094	.243	-.320	1			
7-1. Use of Computers and the Internet for student activities	.408*	.238	.192	.340	.000	.355	1		
7-2. Use of Computers and the Internet for teacher activities	.691**	.027	.454*	.429*	.198	.142	.549**	1	
8. Actual Use of Problem- Based Learning	.426*	.022	.182	.425*	-.223	.686**	.411*	.401*	1

**: Correlation is significant at the 0.01 level (2-tailed)

* : Correlation is significant at the 0.05 level (2-tailed)

The variables related to the Use of PBL

Results show that the use of PBL significantly correlated with computer and Internet skills (r=.426; p<.05) and pedagogical beliefs (r=.425; p<.05). Also, the use of general teaching strategies strongly related to the use of PBL (r=.686; p<.01). Those three correlations show that the higher the level of computer and Internet skills, the more teachers believe in constructivism, and the more teachers use a variety of teaching strategies, the more often they use PBL methods in their classrooms.

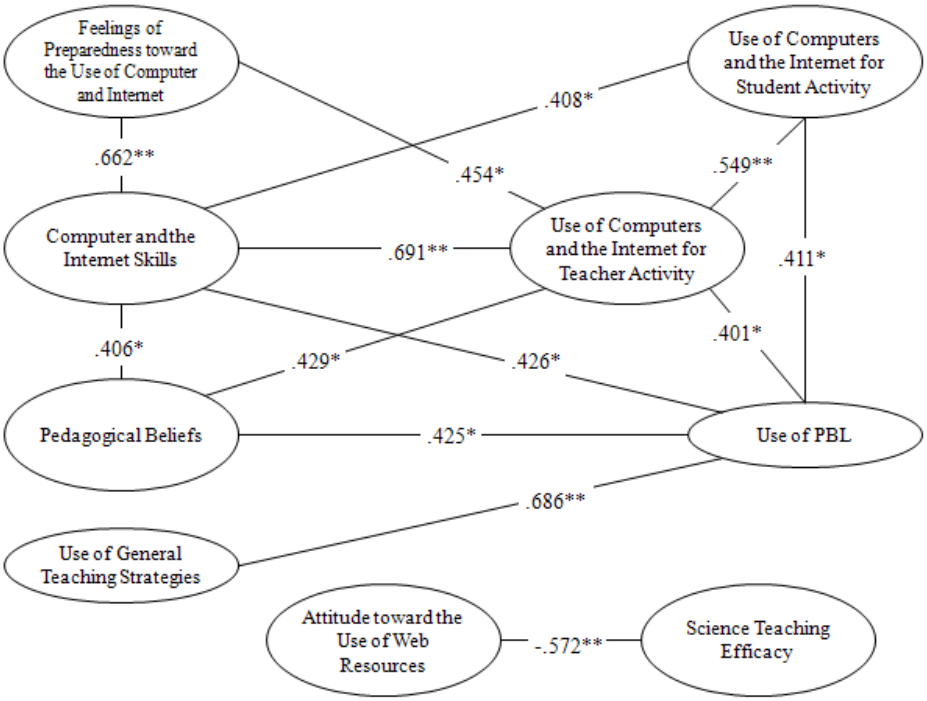
Relationships among the Use of Technology and the Use of PBL

The Use of PBL significantly correlated with both the use of computers and the

Internet for student activities (r=.411; p<.05), and the use of computers and the Internet for teacher activities (r=.401; p<.05).

Relationships among the Predictor Variables

Computer and the Internet skills correlated with feelings of preparedness toward the use of computers and the Internet (r=.662; p<.01) and pedagogical beliefs (r=.406; p<.05). Interestingly, attitude toward the use of web resources negatively correlated with science teaching efficacy (r=-.572; p<.01), which means that a teacher with higher science teaching efficacy tended to have a negative attitude toward the use of web resources. The conceptual framework of correlations between the variables of teacher characteristics and teaching practice appears in Figure 2.



**: Correlation is significant at the 0.01 level (2-tailed)

*: Correlation is significant at the 0.05 level (2-tailed)

Figure 2. Conceptual Framework of Correlational Results

Discussion and Implications

This study aimed to investigate teachers' use of technology and PBL, and examined the interrelationships between various factors regarding teachers' characteristics and teachers' use of technology and PBL. The results suggest some interesting, yet, meaningful implications for the area of teachers' professional development, especially for the programs designed to facilitate the use of web-enhanced Problem-based Learning in classrooms.

First, improving teachers' computer and Internet skills should be considered as an important part of professional development. Since the results support the notion that teachers' computer and Internet skills appear to highly correlate with teachers' use of technology and PBL, the instructional design of a professional development program should have components designed to improve those skills necessary to use technology in appropriate ways. For example, a teacher with a high level of computer skills is likely to adopt more varied teaching strategies such as PBL or an Internet-based activity, and vice versa. This result coincides with prior research, although the correlations were stronger than the initial expectation suggested by the literature review. Moreover, the technology skill part of a professional development program should occur at the beginning, because teachers' technology skill is influential to other variables, such as the feelings of preparedness toward the use of computers and the Internet and pedagogical beliefs (see Figure 2).

Second, teachers' professional development programs should incorporate the area of pedagogical beliefs, which was a critical variable correlating with teachers' use of technology and PBL. Specifically, both cognitive and affective aspects regarding pedagogical beliefs should be considered, since "beliefs" are a mixture of knowledge and attitude. For example, in a teacher professional development program on PBL use, developing a positive attitude toward constructivism as well as understanding the

philosophical assumptions of constructivism could be a reasonable learning objective to build pedagogical beliefs with respect to PBL use.

Although the two variables--computer/internet skills and pedagogical beliefs--are important respectively, a more interesting aspect arises from looking at the relationship between those two variables. A significant correlation appeared between computer and Internet skills and pedagogical beliefs, which suggests a high probability that teachers who have higher levels of computer and Internet skills might accept the constructivist approach. In addition, the research results show that constructivist teachers use computers more often for preparing lessons, doing paperwork, or communicating with students and parents. This result presents a perspective similar to that of prior literature which claims a relationship between teachers' pedagogical beliefs and technology use (Carr-Chellman & Dyer, 2000; Ertmer et al., 2001; Pierson, 2001).

Finally, another aspect to be considered in professional development programs is teachers' attitudes toward web resources, which presented a negative relationship with science teaching efficacy. In other words, a teacher who had higher science teaching efficacy showed a negative attitude toward Internet resources. This can be interpreted as a teacher with high efficacy may not be dependent on online resources, which is quite a surprising result. Teachers' professional development programs should consider how to promote positive attitudes toward the use of web resources for teachers with a high level of self-efficacy.

Overall, the research results suggest meaningful implications for teachers' professional development. In order to improve the way teachers use computers and the Internet in their classrooms, teachers need to be equipped with adequate computer and internet skills, but also they need to have positive attitudes toward the technology (i.e. computer and web resources). In addition, feelings of preparedness

toward using computers and the Internet also affect how teachers use these resources. The higher their level of computer and Internet skills, the more prepared they feel to use these technologies. Developing a positive attitude toward the pedagogy of constructivism may also influence the way they use technology and teaching strategies such as PBL. All in all, the research findings suggest that all of the cognitive, psychomotor/skills, and affective domain regarding technology and PBL use should be integrated in teachers' professional development to influence teaching practice.

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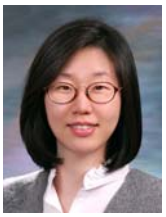

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