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Integrating Technology and Problem-Based Learning: A Comparison of Two Teacher Professional Development Approaches

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Abstract

Abstract: This article presents two technology-oriented teacher professional development (PD) models aimed at helping teachers find high-quality online learning resources and use them in designing effective inquiry learning activities for their students. The models use problem-based learning (PBL) as its cornerstone inquiry approach. In the first enactment, teachers learned PBL design skills concurrently with technology skills, while in the second, the needed technology skills were presented prior to learning about PBL. Results for both enactments indicate large increases in teacher knowledge and attitudes with regards to technology use and integration. Teachers also show sustained usage of the technology over time. In terms of differences between the two enactments, participants who learned technology skills followed by the PBL intervention utilized significantly more PBL features in their learning activities than participants in the technology concurrent with PBL group.

Introduction

The rapidly emerging and evolving *CyberLearning Infrastructure* (Computing Research Association, 2005; Pea et al., 2008) increasingly provides instant access to a growing network of high-quality, open access online resources for teaching and learning. Resources available through this networked environment include innovative curricula, teacher-created lesson plans, as well as interactive tools such as visualizations and simulations that use real-world datasets (Barker, 2009; McArthur & Zia, 2008). When this technical infrastructure is combined with the social aspects of 'Web 2.0' functionality, the intended result is a collaborative network transcending location, time, and educational context. This allows users (e.g., researchers, content developers, teachers, students) to access, create, connect, and share knowledge in ways that can fundamentally transform educational practice and deepen learning in the disciplines (Greenhow, Robelia, & Hughes, 2009).

However, within this seemingly boundless environment, several contextual factors limit the extent to which teachers adopt and adapt the technologies, resources, and pedagogical skills necessary to leverage and make their own contributions to *CyberLearning* environments. In particular, despite teachers' documented beliefs that online resources can enrich their classrooms and improve student learning, they experience many barriers that prevent them from doing so in effective and transformative ways. Barriers are in large part due to the required knowledge for and inherent complexity of effective technology integration (K. Hanson & Carlson, 2005; Kramer, A. Walker, & Brill, 2007; Mardis, 2002; M. Recker et al., 2005).

Teacher professional development (PD) has long been used as a way to increase teachers' knowledge and skills, and many studies have demonstrated its positive effects on instructional practices and student learning (Borko, 2004). However, while much is known about characteristics of effective PD (e.g., intensive, sustained, job-embedded, focused on content, active, and collaborative), these are not precise enough to guide practice (Wayne, Yoon, Zhu, Cronen, & Garet, 2008). Further, there is a dearth of studies that examine long-term impacts of PD on teachers, as well as their students (Lawless & Pellegrino, 2007).

Narrowing the focus, models for teacher technology professional development do indeed exist. On example is *learning by design* (Koehler & Mishra, 2005a), which advocates improving the technological pedagogical content knowledge (Koehler & Mishra, 2008) of teachers through engaging them in meaningful design problems. As teachers find solutions, they acquire the relevant skills and knowledge. Learning by design thus represents a critical building block and while empirical study exists (e.g., Koehler & Mishra, 2005a, 2005b; Koehler, Mishra, Hershey, & Peruski, 2004; Koehler, Mishra, & Yahya, 2007), areas for further exploration remain. For example, fundamental assumptions of the model, such as the need to concurrently address technology, pedagogy, and content knowledge, remain untested.

The purpose of this research is to develop and test a technology-oriented teacher professional development (PD) model that helps teachers find high-quality online learning resources and use them in designing effective inquiry learning activities for their students. As we will describe, our PD model addresses several gaps in the literature. To investigate the PD model's impact, we report results from two, consecutive enactments. Following aspects of user-centered design (Nielsen, 1993) findings from the first enactment informed the design of the second. In particular, because prior research is lacking on effective PD models for technology integration, in the first enactment, teachers learned PBL design skills concurrently with the technology skills, while in the second, the needed technology skills were presented prior to learning about PBL. Results are reported in terms of impact on teachers' knowledge, attitudes, and design activities, as well as on the extent they integrated PBL into learning activities for their students.

In the next sections of this article, we describe the primary inquiry-based approach underlying the PD model, problem-based learning, as well as the technology context for the PD. We then describe the method and present results from two enactments of the PD model. Results show large increases between pre- and post-survey responses, high usage of online resources, and an increase in using PBL. In terms of differences between the two enactments, participants who learned technology skills followed by the PBL intervention utilized significantly more PBL features in their designs of inquiry learning activities than participants in the technology concurrent with PBL group.

Theoretical Framework

PBL is a well-established inquiry-oriented instructional method, originally developed in medical education, and now used in K-12, university settings, and beyond in both formal and informal settings (Savery, 2006). In PBL, learners acquire knowledge through engaging with authentic and challenging problems (Barrows, 1986; Barrows & Tamblyn, 1980; Savery, 2006). Typically, learners operate in small groups to solve these authentic problems using resources made available to them. The instructor acts as a facilitator, provides scaffolds and coaching, and models the kinds of meta-cognitive questions that students eventually take on (Hmelo-Silver & Barrows, 2008). Each problem cycle concludes with a reflection phase, in which learners discuss the efficacy of the information obtained and their solution strategies (Barrows, 1986).

Over time, several of the institutions utilizing PBL made adaptations to the model to fit their own unique needs (Barrows, 1996). In this research, we define PBL as consisting of: 1) authentic problems, 2) a learner centered approach, 3) teachers acting as facilitators or guides, and 4) small group interactions. This definition forms a baseline for all facets of our work, with adaptations or changes clearly noted.

Overall, research shows that PBL is successful in promoting student learning. Recent meta-analyses show generally favorable results (Gijbels, Dochy, Van den Bossche, & Segers, 2005; Walker & Leary, 2009). Further, there is agreement across several meta-analyses that PBL students retain more of what they learn (Barneveld & Strobel, 2009). PBL findings specific to classroom teachers are even more dramatic. Our own meta-analysis of several quantitative studies shows a large (d = 1.14) effect size. Of the available research, one study attempted to improve teaching and learning practices (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006) and one had a central goal of teaching technology skills (Gulseçen & Kubat, 2006). None of the studies we identified attempted to combine the two, and promote changes in the practice of teaching and learning alongside technology skills.

Technology Context

The technology context for the professional development is **the Instructional Architect (IA.usu.edu)**, a lightweight, web-based tool in which teachers can quickly and easily find online resources and design learning activities for their students (Recker et al., 2005). Table 1 shows statistics on usage since August 2006, and growth in the IA over the last 12 months. The system is starting to garner widespread use and spread 'virally' to teachers not directly attached to our professional development workshops.

Table 1. Instructional Architect usage data (to April, 2010).

	N	*12-month growth*
Registered users	4,149	34%
IA projects created	8,505	47%
Online learning resources used	40,516	57%
Visits to IA project (since 8/2006)	809,216	68%

Teachers can use the IA in several ways. First, once logged in, the **'My Resources'** area allows teachers to directly search for and save links to online learning resources from the Web and educational content repositories such as the National Science Digital Library (NSDL.org). Resources that can be linked include online content and Web 2.0 technologies like RSS feeds and podcasts. Second, in the **'My Projects'** area, teachers can assemble and organize these linked online resources to design learning activities (called IA Projects). Teachers can include accompanying text to provide instructions for their students. Finally, teachers can **'Publish'** their IA projects for their own students, or anyone on the web.

Professional Development Model

To address both the underutilization of the growing base of *CyberLearning* environments and resources, and to promote their transformative use, we developed a technology-oriented teacher professional development (PD) model. In this model, teachers learn to design problem-based learning (PBL) activities that engage students in solving authentic problems using online learning resources. To support teachers as designers of PBL activities using online resources, participants learn to use the Instructional Architect tool, described above.

The professional development model used in the present research is implemented as a series of workshops, conducted as face-to-face sessions over three months, with in-between classroom activities. Incorporating important, research driven characteristics (Desimone, 2009; Wayne et al., 2008), it is sustained, centered on authentic problems, content focused, active, and collaborative (see Figure 1). The workshop itself is modeled on PBL in that participants engage with authentic and complex design problems in their own teaching, generate solutions, and reflect with their peers on the design's success.

The PD model focuses on the following technology skills: 1) finding and using online learning resources, and 2) designing activities for students using the IA. The pedagogical content focuses on learning to design problem-based learning activities for students. Participants were encouraged to utilize PBL with their students only if they felt it aligned with their self-selected design problem, the needs of their students, and their own beliefs about teaching and learning.

As noted above, while PBL has been used with success in helping teachers' gain technology skills, or improve their teaching and learning practices, few studies appeared to combine the two and promote changes in the practice of teaching and learning alongside technology skills. In this way, our PD model addresses an important gap in the literature.

Moreover, the literature on teacher technology integration is unclear as to how these skills are best learned. Pure PBL, as defined by Barrows (1986), suggests that learning occurs in service of solving authentic problems. Learning By Design (Koehler & Mishra, 2005a;

Koehler et al., 2004) recommends that teachers learn about all elements of technology integration in a connected way, rather than teasing these components apart into constituent skills. With this in mind, in the first enactment of our PD model, teachers learned PBL design skills concurrently with the technology skills.

However, in a post-workshop evaluation focus group, participants from the first enactment indicated that learning new pedagogy and technology skills concurrently was too difficult, and suggested they be learned separately (Robertshaw, Walker, Recker, Leary, & Sellers, 2010). This sentiment meshes with some PBL research suggesting that PBL can be challenging (Arambula-Greenfield, 1996), to the point of requiring more time and effort on the part of learners (Surlekar, 1998). In response to this literature and the needs of our participants, the second enactment of the workshop model separated the needed technology skills from PBL.

Methods

This section describes the methods used in an empirical study of two enactments of the professional development model, both of which promote technology skills and use of PBL. The study addressed the following research questions:

1) To what extent do workshop participants show changes in their knowledge and attitudes towards technology integration in teaching?

2) Do participants from both workshops have similar increases in their knowledge and attitudes towards technology integration in teaching?

3) To what extent do workshop participants employ PBL as demonstrated in their designed activities?

4) Do participants from both workshops engage in similar usage of PBL in their designed activities?

5) How do participants in the two workshops describe technology integration and PBL?

In order to address these research questions, a mixed method approach was used (Creswell, Clark, Gutmann, & Hanson, 2003). Quantitative research was the primary emphasis, used to address the first four research questions. Qualitative data were gathered in parallel and analyzed subsequently to address the final research question (Johnson & Onwuegbuzie, 2004).

Participants

Two enactment of the PD model were conducted. The *technology concurrent with pedagogy* enactment took place in Fall 2008 (*N*=23). The *technology followed by pedagogy* enactment took place in Spring 2009 (*N*=19). All participants consisted of classroom teachers drawn from the same rural school district. Teachers received 1 university credit for completing all workshop requirements. The drop rate for the study was high, 22% (N=5) in the Fall and 30% (N=6) in the Spring, due to incomplete data.

Study Procedures

Figure 1 shows key activities for the two workshop enactments. In the technology concurrent with pedagogy model, participants learned needed technology skills while learning about PBL as an instructional approach. In the technology followed by pedagogy model, the same technology skills were learned separately and prior to PBL. Total workshop time was five hours, spread over two meetings for the technology concurrent group. The technology followed by pedagogy group met three times for two hours each day and had an additional round of between workshop activities. Between workshop activities consisted of finishing class activity designs, implementing and then reflecting on the use of the activity in the classroom. Figure 1 shows a summary of the amount of time devoted to technical skills (use of the IA), pedagogical skills (PBL), and time provided for participants to design instructional activities. Remaining time was devoted to discussion, administrative functions, and breaks.

Figure 1. Workshop Enactments

Technology concurrent with pedagogy (Fall 2008), 2.5 hour workshops	**Technology followed by pedagogy (Spring 2009), 2 hour workshops**
Workshop 1	
• Divide into small groups • Demonstrate use of the IA • Participants select design problem • Introduce online resources and IA • Initiate discussion about PBL • Review critical elements of PBL • Groups begin to design IA project(s) *Technical skills (60 minutes)* *Pedagogical skills (60 minutes)* *Design time (15 minutes)*	• Demonstrate use of the IA • Introduce online resources and IA • Walk through sample project creation • Participants select design problem • Individuals design IA project(s) *Technical skills (60 minutes)* *Pedagogical skills (0 minutes)* *Design time (45 minutes)*
Between workshops	
• Design and implement IA project(s) • Reflect on barriers and successes	• Design and implement IA project(s) • Reflect on barriers and successes
Workshop 2	
• Review use of the IA • Small and large group discussion of implementation experiences • Participants revisit instructional problem *Technical skills (30 minutes)* *Pedagogical skills (60 minutes)* *Design time (45 minutes)*	• Review use of the IA • Small and large group discussion of implementation experiences • Engage in example PBL activity • Review critical elements of PBL • Groups begin to design new IA project(s) *Technical skills (15 minutes)* *Pedagogical skills (60 minutes)* *Design time (30 minutes)*
Between workshops	
	• Design and implement IA project(s) • Reflect on barriers and successes
Workshop 3	
	• Small and large group discussion of experiences *Technical skills (15 minutes)* *Pedagogical skills (60 minutes)* *Design time (30 minutes)*

Both workshop enactments had substantive departures from Barrows' model (Barrows, 1986, 1996) for PBL. The largest difference was the origin of the problem, with participants selecting a need for their own classrooms as opposed having a design problem selected for them. This was a conscious trade-off between authenticity and content coverage. While a pre-selected problem might force participants to discover desired technical and pedagogical skills teachers may not have that problem in their classroom. As a result, they would be asked to design materials that could not be used in their classroom. Instead, teachers were asked to think of a current instructional need for their students, assuring authenticity for workshop participants.

The other main difference was group work. Technology concurrent participants formed groups and worked on one initial design together. After receiving feedback from participants, we concluded that the authenticity gain of self-selected problems was lost when participants were asked to work on the problem of another teacher. Therefore, group activities in the technology followed by pedagogy workshop consisted solely of reflection and evaluation of individually generated problem solutions, and group participation in the sample PBL activities.

Data Sources

At the start and end of the PD, participants completed online surveys, consisting of Likert scale and open-ended items. Items were adapted from an established measure (Becker, 2000) of teacher knowledge, and attitudes with respect to technology and teaching**.** Web usage data (Khoo et al., 2008) of participants' design activities, and their students' use of the Instructional Architect were also automatically captured. After implementing their activities, participants wrote about their use in the classroom in a reflection paper.

As part of the workshop, participants were asked to design PBL activities using the Instructional Architect and then implement them in their classrooms. To measure participant alignment of their designed IA projects with PBL, an established coding rubric was employed (Walker & Shelton, 2008). The rubric scores the presence or absence of 14 PBL elements in 4 general categories (see Table 2).

Table 2. Problem-based learning coding rubric.

PBL Element	Description
Authentic Problems	Problems are complex (cross-disciplinary).
Authentic Problems	Problems have multiple solution paths.
Authentic Problems	Problems are ill-structured.
Authentic Problems	Problems are likely to be encountered in professional practice.
Learner Centered	Learners generate objectives from given (and unresolved problems).
Learner Centered	Learners are prompted to locate resources (content experts, reference books, journals articles) that will assist in problem resolution.
Learner Centered	Learners are prompted to utilize resources (content experts, reference books, journals articles) that will assist in problem resolution.
Learner Centered	Learners engage in self and/or peer assessment of problem solving performance within their group.
Teachers as Facilitators	Facilitators model and prompt students with meta-cognitive questions that assist in problem resolution.
Teachers as Facilitators	Facilitators are guides.
Small Group Interaction	Learners interact in groups.
Small Group Interaction	Divide and conquer.
Small Group Interaction	Learners share and discuss their findings.
Small Group Interaction	The group evaluates the utility of the acquired knowledge in solving the problem.

Raters consisted of research team members who were blind to the source of the IA project. Each project received three ratings from a randomly selected pool of judges. A one way random effects intra-class correlation (ICC) was calculated to determine the reliability of raters for the available data (Patrick Shrout & Fleiss, 1979). The resulting ICC of 0.89 indicates a substantial level of intra-rater reliability for these data. Once rated, mean values for each project were computed and used in subsequent analyses as the PBL score. Note that the scores only apply to the design of PBL activities as reflected in IA projects, and thus are likely an under-estimate of actual PBL use in the classroom. Teachers may be incorporating small group interactions, for example without making explicit mention of them in their IA project.

Quantitative Results

The quantitative portion of the study used a non-equivalent control group design (Campbell & Stanley, 1963). Covariates were used to account for pre-existing differences in teacher experience, knowledge, and confidence with technology integration. Results are presented in terms of participants' 1) design activities using online content as measured by web metrics, 2) knowledge of and attitudes toward workshop content as measured by pre/post-surveys, and 3) use of problem-based learning elements in designing activities for students, or the mean PBL score as measured by the PBL rubric.

Design Activities

Web usage analyses show a large number of logins to the IA, created IA projects, online resources used, and project visits (see Table 3). These measures suggest successful workshop impact on participants' technology integration skills. For the most part participants from both workshops exhibited similar trends in their usage with the exception of the number of project visits. Technology concurrent participants showed fewer visits per project (M = 71.36) then participants in the technology followed by pedagogy workshop (M = 114.41).

Table 3. Participants' activities as measured by IA Web usage data.

	M	*SD*	*Max*
Technology concurrent with pedagogy (N = 18)			
Number of participant logins to the IA	26.72	21.53	92
Number of IA projects created	6.68	4.88	17
Number of online resources used	27.52	27.82	105
Number of visits to IA project (N > 1)	71.36	117.99	888
Technology followed by pedagogy (N = 13)			
Number of participant logins to the IA	27.50	17.96	72
Number of IA projects created	7.00	5.90	27
Number of online resources used	29.72	43.71	178
Number of visits to IA project (N > 1)	114.41	142.71	1724

For both groups, the mean number of times each IA instructional project was accessed is also large, indicating high student usage of the IA projects and their associated online learning resources. Finally, as a glimpse of long-term impact, 14 (77%) of Fall 2008 and 8 (61%) of Spring 2009 participants were still active IA users 6 months later. Since PD studies seldom report long-term impact data (Wayne et al., 2008), it is hard to know how these results compare.

Knowledge and Attitudes

Research question one addresses changes in the knowledge and attitudes of all workshop participants. Those changes appear to be substantial. Table 4 reports large pre-post gains in all areas for both groups. Cohen (1988) describes effect sizes (*d*) of .8 as large, something that would be visible to a casual observer. All of the pre-post gains are .88 or greater. Reported gains in experience are about the same for the technology concurrent (*d* = 1.11) and technology followed by pedagogy (*d* = 1.14) workshop participants. Gains are nearly or more than twice as large for the technology followed by pedagogy participants for both knowledge (*d* = 1.56) and confidence (*d* = 1.86) when compared to the technology concurrent participants (*d* = 0.88). Effect size increases are due to a combination of larger mean difference, as well as substantially smaller standard deviations in the technology followed by pedagogy group.

Table 4. Participants self-report on technology integration knowledge and attitudes

	Pre-survey		**Post-survey**			
	M	***SD***	***M***	***SD***	***Adj. M***	***d***
Technology concurrent with pedagogy (*N* = 18)						
Experience creating online lessons	1.44	1.25	2.72	0.96	2.67	1.11
Knowledge using technology in classroom	2.00	1.14	2.78	0.94	2.76	0.88
Confidence in teaching with technology	2.06	1.16	2.83	0.79	2.84	0.88
Technology followed by pedagogy (*N* = 13)						
Experience creating online lessons	1.57	1.26	2.91	0.76	2.97	1.14
Knowledge using technology in classroom	1.83	0.90	2.83	0.55	2.86	1.56
Confidence in teaching with technology	2.08	0.76	3.00	0.58	2.99	1.86

Note. Possible values range from 0 = low to 4 = high. Maximum observed values for all measures, time points, and groups is 4.

To answer *research question two* about group differences in knowledge and attitudes a MANCOVA was employed. Covariate candidates included teacher experience, knowledge, and confidence as measured by the pre-survey. Experience was removed as a covariate since it was not predictive of any of the three outcomes, and because two covariates are preferred given the number of groups ($N = 2$) and research participants ($N = 31$) (Huitema, 1980). The MANCOVA revealed no main effect for workshop intervention $F(3, 25) = .33$, $p = .81$ suggesting that both groups had similar results for levels of experience, knowledge, and confidence at the conclusion of their respective workshops.

Teacher Design using Problem-Based Learning

Research question three examines usage of PBL in teacher designed activities. Table 5 shows overall scores for each workshop group on the presence of PBL in finished IA projects. Recall from the workshop enactment designs (Figure 1) that technology concurrent participants had one opportunity to design and implement IA projects after receiving a combination of technology and pedagogy training. The technology followed by pedagogy group had two opportunities to design and implement: the first after receiving technology, and then a second after receiving pedagogy training in the second workshop. Adjusted means are corrected for pre-existing differences on the pre-survey results.

Table 5. Overall score for elements of problem-based learning in IA projects

	N	*M*	*Adj. M*	*SD*	*Max*
Technology concurrent with pedagogy					
after tech and pedagogy	18	2.63	2.48	2.73	7.99
Technology followed by pedagogy					
after tech only	13	1.97	2.04	1.80	4.54
after tech and pedagogy	13	4.54	4.68	2.92	13.67

Note. Possible scores range from 0-14.

All of the scores were low and positively skewed with only a handful of participants scoring high. To investigate *research question four* and explore differences between enactments, we conducted an ANCOVA. Statistically significant differences were found among the three sets of IA projects $F(2, 38) = 3.15$, $p = .05$. After receiving both technology and pedagogy concurrently (*Adjusted M* = 2.48), teachers were marginally more likely (d = 0.08) to use PBL than teachers who received technology skills alone (*Adjusted M* = 2.04). An effect size difference of .08 would be hard for someone experienced in PBL to detect in looking through teacher projects, or may not be detected at all (Cohen, 1988). In contrast, after receiving technology skills followed by the pedagogical intervention (*Adjusted M* = 4.68), workshop participants utilized more PBL features than after technology alone (d = 0.45), or after technology integrated with pedagogy (d = 0.29). At all three time points, participants used parallel amounts of each PBL feature. Authentic problems were most evident, followed by learner centered, teacher as facilitator, and small group interaction. See Table 6 for all unadjusted mean scores.

Table 6. Scores for each element of problem-based learning in IA projects.

PBL Element (scale)	**Technology concurrent with pedagogy** (after both)			**Technology followed by pedagogy** (after tech only)			**Technology followed by pedagogy** (after both)		
	M	***SD***	***Max***	***M***	***SD***	***Max***	***M***	***SD***	***Max***
Authentic Problems (0-4)	1.20	1.35	3.67	1.00	0.90	2.67	1.92	1.55	4.00
Learner Centered (0-4)	0.91	0.82	2.67	0.62	0.65	2.00	1.28	1.15	3.67
Teacher as Facilitator (0-2)	0.30	0.47	1.33	0.31	0.44	1.33	0.64	0.63	2.00
Small Group Interaction (0-4)	0.22	0.47	1.33	0.05	0.19	0.67	0.69	1.29	4.00

At all three time points, participants' IA projects showed the highest means for use of authentic problems, and the lowest means for small group interactions. The fact that small group interaction had the lowest means is particularly surprising given that teacher as facilitator had only two points possible. Overall, there is quantitative support for the notion that separating the pedagogy and technology portions of the workshop promotes increased use of the pedagogy.

Qualitative Findings

The qualitative portion of the study consisted of a constant comparative analysis (Corbin & Strauss, 2008) of teacher reflection papers. Purposeful selection was used with the goal of finding representative participants based on the quantitative data. PBL scores were given equal weight with a combination of the experience, knowledge, and confidence post-survey scores to rank participants. One participant was then selected from the *lower*, *middle*, and *upper* third from each of the two workshop enactments (total $N = 6$). Data came from teacher journals, in which teachers discussed their efforts to integrate technology in the classroom and explained their decision to use or not use PBL.

As summarized in Table 7, and in response to *research question five* participants from each workshop group appear to differ in their characterizations of technology integration and problem based learning. Categories for analysis were broken into two general areas: comments pertaining to technology integration, and comments pertaining to problem-based learning. Technology integration and problem based learning comments were further broken into six sub-categories each, which emerged from analyzing themes in participants' reflection papers. To protect the privacy of respondents, names are withheld. Instead, quotes are associated with each participants' workshop (*technology concurrent* or *technology followed by pedagogy*) and placement (*lower*, *middle*, or *upper*).

Table 7. Frequency (%) of participant comments addressing Technology Integration and PBL.

Categories	Technology concurrent with pedagogy *f*(%)	Technology followed by pedagogy *f*(%)
Technology Integration		
Resource Access	1(8%)	2(29%)
Technology Knowledge	6(46%)	2(29%)
Time	2(15%)	1(14%)
Technology Pedagogy	1(8%)	2(29%)
Alternatives	1(8%)	0(0%)
Dissemination	2(15%)	0(0%)
Total	13	7
Problem-based learning		
Problem	1(14%)	3(23%)
Facilitator	1(14%)	1(8%)
Exploration	2(29%)	1(8%)
Resources	0(0%)	2(15%)
Grouping	2(29%)	5(38%)
Synthesis	1(14%)	1(8%)
Total	7	13

When a response emerged that was different from previously coded responses, a new category was created. For example, the *lower* teacher in the technology concurrent group described changes to how she organized her IA project: “One thing I will change is to put links of similar difficulty together. I think it will help struggling students feel more successful when they can play all the games under one link.” This differed from a comment about technology access made by an *upper* teacher in the technology concurrent group: “It is important for interested students to have access to online resources that will give them the information they need.” To capture this distinct notion, we created a separate sub-category.

Other responses were deemed to overlap. For example, one teacher discussed problems presented to students: “My second project was created to help students understand the volume of a prism and it’s real life application. The problem was presented to the entire class . . . ” (medium, technology followed by pedagogy group). The idea of real life application overlapped with a statement about the kind of work content driving usage of the tool: “I will be using the technology and IA project to answer more of the ‘when am I ever going to use this?’ questions” (upper, technology followed by pedagogy).

As shown in Table 7, technology concurrent participants tended to make more statements about technology integration. This is reflected in both an increased focus on the technology knowledge category, as well as more diverse comments covering nuances such as dissemination and alternatives. Technology followed by pedagogy participants engaged more often in discussions of problem-based learning. For the most part, this represented an increase in frequency across the same categories as the technology concurrent group. The technology followed by pedagogy participants were the only ones to discuss resources, a critical component of PBL in which students are asked to find and utilize resources in pursuit of their problem solution.

Conclusion and Limitations

Results indicate that participants showed large gains in terms of their knowledge and attitudes after participating in both enactments of the professional development model. Web usage data showed teachers designing activities using the IA, both during and well after the workshop. Quantitative results showed no differences in teachers' self reported knowledge, experience, and confidence in technology integration between the two workshop enactments. While this may be partly due to the rather low degrees of freedom, the adjusted mean scores are fairly close.

In contrast to the self-reported quantitative data, findings from a qualitative analysis of the reflection papers of three participants in each of the workshop enactments suggested some differences in their discussions. In particular, participants in the technology concurrent with pedagogy group engaged in a more in depth as well as a broader discussion of technology integration in their reflection papers. It is possible that the quantitative measures are not sensitive to detect differences between workshop groups but this seems unlikely given they are sensitive enough to detect pre-post gains within each group.

The overall presence of PBL elements in teacher-designed activities was low. This result is not surprising as, for most teachers, PBL represents a dramatic shift in practice. In addition, participants were encouraged to use PBL only to the extent that it fit with their beliefs about teaching and learning, met the needs of their students, and aligned well with their chosen design problem. Finally, the rubric was applied to teacher projects rather than how they were used in the classroom. Teachers may have facilitated more than lectured, or used student groups in ways that were not immediately apparent in the project by itself. Thus the rubric may have underestimated the level of PBL actually used in the classroom as reflected in any given IA project. The presence of PBL did markedly increase when pedagogy was addressed separately from and subsequently to technology skills. In contrast to knowledge, experience, and confidence with technology integration quantitative, PBL data were not self-reported by teachers but rather evaluated by the research team. The qualitative PBL findings paralleled the qualitative results. Teachers engaged in far less discussion of

PBL when they received the technology and pedagogy elements concurrently. Overall, the data both support and diverge from the integrated approach advocated in learning by design.

Limitations to this work include participant self-selection, a lack of classroom observations, and differences between the two workshop enactments. As noted above, the two workshop enactments differed in terms of the amount of time spent on the various activities and, as such, direct comparisons remain problematic (see Figure 1).

Moreover, as described, departures were made from "pure" problem based learning. The interventions also departed from learning by design. Prior efforts make note of technology being emergent and particpant selected, where as the technology tool for this study was selected a priori. At first glance, the lack of content knowledge as an explicit component of the workshop seems to depart from learning by design but there is precedent. Graduate students have partnered with faculty gaining exposure to content only as part of the design activity, in-service teachers have been asked to create videos relating to their existing understanding of library sciences, and finally teachers have been asked to re-design existing materials specifically to avoid researching the topic and allow an increased focus on the process of design (Koehler & Mishra, 2005a). Beyond teasing apart technology and pedagogy in the second enactment, the workshops involved less group work and took less time. Prior learning by design efforts have been associated with university classes spanning an entire semester (Koehler & Mishra, 2005a, 2005b; Koehler et al., 2004). Replication work with a more sustained intervention and participant driven technology skills is needed to determine if the results found in this study persist.

Future work includes examining the impacts of engaging students in PBL activities using online resources. Data collection is currently underway to support a Hierarchical Linear Model of student outcomes with teachers as the grouping variable. In addition, while the initial reliability of the PBL design rubric for these data is encouraging, it remains to be seen if that success can be repeated with other samples. Finally, we plan to conduct classroom observations when teachers are implementing their IA projects to examine if their classroom strategies differ.

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