US-China Education Review B 5 (2012) 510-520
Earlier title: US-China Education Review, ISSN 1548-6613

Designing for Problem-Based Learning: A Comparative Study of Technology Professional Development*

Lei Ye, Andrew Walker, Mimi Recker,
M. Brooke Robertshaw, Linda Sellers
Utah State University, Logan, USA

Heather Leary
University of Colorado at Boulder,
Boulder, USA

Despite of much focus on professional development aimed specifically at developing teachers' technology integration skills, rigorous studies of effective PD (professional development) are lacking. Evidence is also lacking on how these skills can best be integrated with pedagogical and content knowledge to improve student learning. The purpose of this article is to present two "design-oriented" TTPD (technology-related teacher professional development) designs and investigate the designs' impact on teachers. In one TTPD (*tech-only*), teachers learned technology skills to create activities using online learning resources. In the other (*tech+PBL*), teachers learned to create PBL (problem-based learning) activities using online resources. All teachers implemented these activities with their students. Findings indicate similarities and differences across several outcomes, including teacher knowledge, teacher attitude, usage of PBL and Web usage data. In addition, an instrument was developed to measure the students' self-reported knowledge, attitudes and behavior regarding their teachers' implemented activities. The instrument was shown to be valid and reliable.

Keywords: technology-related teacher PD (professional development), PBL (problem-based learning), math and science education

Introduction

The increased pervasiveness of Internet technologies in school settings provides an instant access to a growing Network of high quality and open access "online resources" for education (Ainsworth, Honey, & Johnson, 2005; McArthur & Zia, 2008; Borgman et al., 2008). These online learning resources include a wide array of simulations, data sets and lesson plans. As such, they have a substantial, yet largely untapped potential to support teachers in creating tailored activities that enhance diverse students' educational experiences.

***Acknowledgement:** The authors would like to thank the participating teachers. This material is based in part upon work supported by the National Science Foundation under Grant Numbers 0937360. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Lei Ye, Ph.D. candidate, Department of Instructional Technology and Learning Sciences, Utah State University.
Andrew Walker, Ph.D., associate professor, Department of Instructional Technology and Learning Sciences, Utah State University.
Mimi Recker, Ph.D., professor, Head of Department of Instructional Technology and Learning Sciences, Utah State University.
M. Brooke Robertshaw, Ph.D. candidate, Department of Instructional Technology and Learning Sciences, Utah State University.
Linda Sellers, Ph.D. candidate, Department of Instructional Technology and Learning Sciences, Utah State University.
Heather Leary, research associate, Institute of Cognitive Science, University of Colorado at Boulder.

However, as widely documented, teachers often lack the time and technology skills necessary for effective technology integration (Hanson & Carlson, 2005; Kramer, Walker, & Brill, 2007). As such, teachers need support in developing their capacity to teach effectively in 21st century classrooms.

Studies have shown that teacher PD (professional development) is an effective way to improve teacher skills, knowledge and attitudes (Borko, 2004). The increase in technology use in school has seen a concomitant increase in technology-related professional development (Means, Murphy, Javitz, Haertel, & Toyama, 2004). Within this arena of research, efforts have focused on conceptualizing and measuring the intersection of TPACK (teacher technological, pedagogical, and content knowledge) and corresponding ways to improve that knowledge set through professional development (Angeli & Valanides, 2005; Koehler & Mishra, 2005, 2008). Alongside the rich literature base, there are several disagreements about fundamental tenets of TPACK and much work remains to improve the theoretical base for the construct (Angeli & Valanides, 2009). At times, the practice of measuring TPACK appears to be at odds with its theoretical definition. For example, there is a tacit assumption among some that TPACK is a constitutively defined construct.

Yet, despite much PD aimed specifically at developing technology integration skills, rigorous empirical studies of effective PD is lacking. Moreover, evidence is lacking on how newly learned technological skills can best be integrated with pedagogical and content knowledge in ways that improve student learning (Lawless & Pellegrino, 2007)

The purposes of this article is to present two design-oriented technology integration professional development (TTPD) models and investigate their impact on teacher and student learning. In one design (*tech-only*), teachers learned technology skills coupled with a self-chosen pedagogy to create student activities using online resources. In the other (*tech+PBL*), teachers learned technology skills to create inquiry-oriented (specifically PBL (problem-based learning)) activities for their students using online resources. In this way, our study compared the impact of a TTPD design focused on integrating technology with a self-chosen pedagogy alone, with one integrating technology and pedagogy.

The Theoretical Framework

Teacher professional development has long been a way to increase teachers' skills and studies have demonstrated its positive effects on instructional practices and resultant student learning (Borko, 2004). Previous studies have identified general characteristics of effective PD (e.g., intensive, sustained, job-embedded, collaborative, active and content focused). However, rigorous evidence of effective PD, especially with regards to long-term impacts on teacher and student learning is lacking (Wayne, Yoon, Zhu, Cronen, & Garet, 2008).

The TTPD design used in the present research is design-oriented in that participants learn to design instructional activities for their students. Proponents of design-oriented PD argue that this approach enables teachers to learn new technology skills within an authentic instructional context. This helps them take ownership of new skills, making them more likely to integrate these into future teaching (Lawless & Pellegrino, 2007). This perspective also fits with a more contemporary view of teaching as a kind of design task, in which teacher adaptation and use of materials are seen as a critical step in curriculum design (Brown & Edelsen, 2003; Remillard, 2005).

The Technology Context

The technological context for the TTPD is a free and Web-based tool, called the IA.usu.edu (instructional architect). The IA supports teachers as designers of instructional content, allows them to create instructional activities for their students using online resources and package their designs as Web pages. There are several different ways for teachers to use the IA. Within "My Resources" area, teachers can search for online resources from the Web, and once found, save them into folders. Resources can include anything with a valid URL (Uniform Resource Locator), such as RSS (Really Simple Syndication) feeds, podcasts, Web pages, PDF (Portable Document Format) documents or graphics among others. The "My Projects" area (see Figure 1) allows teachers to select from their saved online resources, group them together, sequence them, and provide directions, lead questions, prompt or other form of annotation to create learning activities (called IA projects throughout the remainder of the manuscript article). The "Publish" area gives teachers control over who can view their work, which can be completely private, viewable only by students with a login or completely public to anyone with Web access. In addition, teachers who are logged in have the ability to copy public projects from other teachers. This allows them to take an existing project and adapt it for their own classroom use.

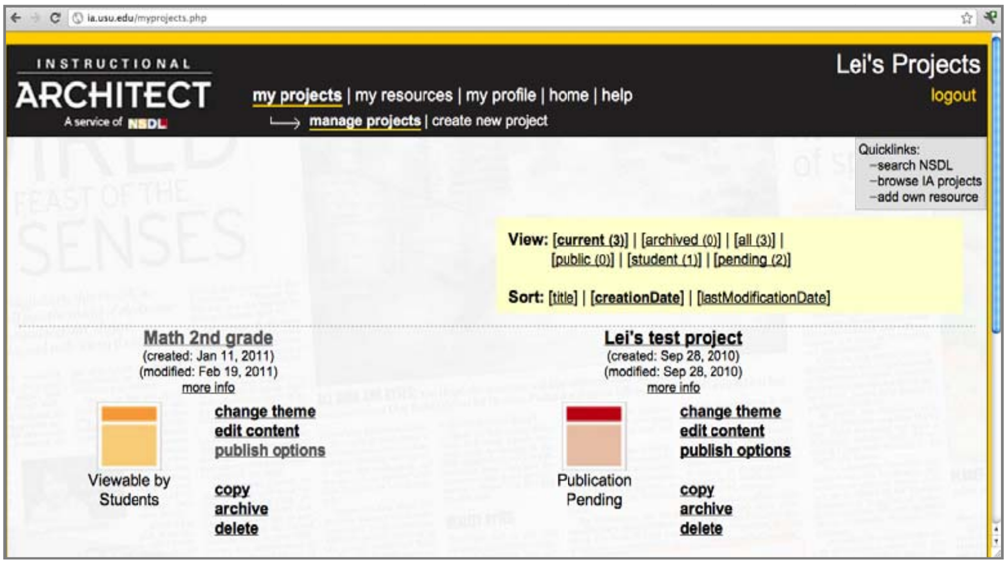
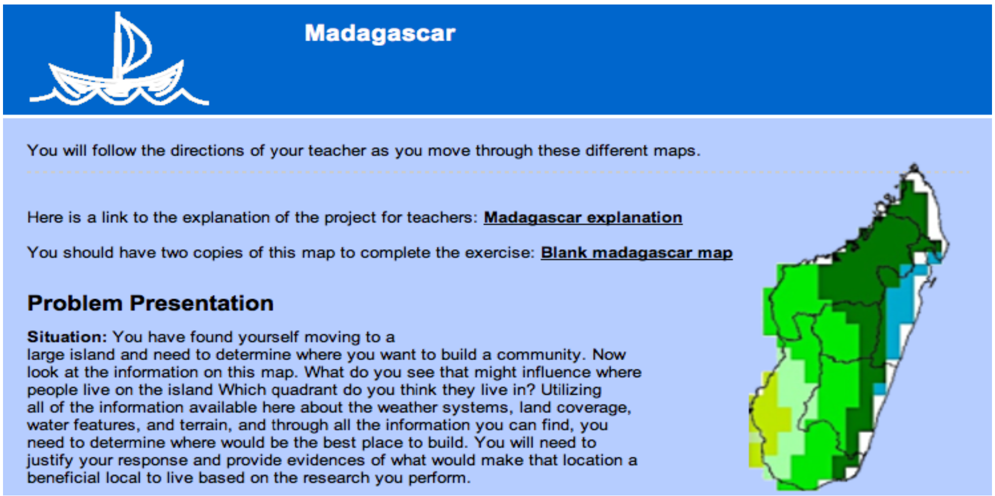


Figure 1. Illustration of a user managing IA projects in the "My Projects" area.



Madagascar

You will follow the directions of your teacher as you move through these different maps.

Here is a link to the explanation of the project for teachers: **Madagascar explanation**

You should have two copies of this map to complete the exercise: **Blank madagascar map**

Problem Presentation

Situation: You have found yourself moving to a large island and need to determine where you want to build a community. Now look at the information on this map. What do you see that might influence where people live on the island Which quadrant do you think they live in? Utilizing all of the information available here about the weather systems, land coverage, water features, and terrain, and through all the information you can find, you need to determine where would be the best place to build. You will need to justify your response and provide evidences of what would make that location a beneficial local to live based on the research you perform.

Figure 2. Example IA project, showing teacher annotations (text) and two forms of online resources: Hyperlinks and an embedded graphic.

Since 2005, the IA has over 7,100 registered users who have gathered over 70,000 online resources and created over 15,900 IA projects. Since August, 2006, public projects have been viewed over 1.5 million times. Figure 2 shows an example IA screen shot with a teacher-created inquiry activity and an embedded online resource.

Research Design

The study was conducted to compare the impact of two TTPD designs, using a non-equivalent pre-/post-test control group design (Campbell & Stanley, 1963). Table 1 shows the study's research questions, data sources, and analyses.

Table 1

Research Questions, Data Sources and Analyses

Research question	Data source	Analysis
1. What is the impact of the two TTPD designs on teachers' knowledge about, attitude towards, and experience with technology integration?	Teacher pre-/post- survey	Descriptives Friedman tests
2. What is the impact of the two TTPD designs on teachers' usage of the IA?	Web usage data	Descriptives
3. What is the impact of the two TTPD designs on PBL use in designing IA projects?	PBL alignment score	Descriptives Mann-Whitney U tests
4. Is the self-reported student questionnaire a valid and reliable instrument?	Student questionnaire	Descriptives Factor analysis

PD (Professional Development) Designs

The TTPD designs were a series of three workshops with in-between activities and were conducted face-to-face over three months. Following key principles of effective PD, they were sustained, content focused, active, and collaborative (Borko, 2004). Following design-oriented approaches in technology integration professional development (Lawless & Pellegrino, 2007), the participants engaged with authentic and complex problems in their own teaching. In an effort to resolve those problems, teachers designed solutions, implemented their designs in the classroom and reflected with their peers on the instructional efficacy of their designs.

In terms of technology content, the TTPD designs focused on the following technology skills: (1) finding and using online resources; (2) designing activities for students using the IA; and (3) implementing these IA projects in the classroom. In one design (*tech-only*), participants solely learned skills to design activities for their students using the IA, a self-chosen pedagogy, and online resources and the IA. In the other design (*tech+PBL*), participants learned technology skills to design inquiry-oriented activities for their students using online resources and the IA. The particular inquiry approach was PBL, wherein students acquire knowledge through engaging with authentic problems (Barrows, 1986; Barrows & Tamblyn, 1980; Savery, 2006). In PBL, learners operate in small groups to solve authentic problems using resources made available to them. The instructor facilitates, scaffolds, coaches, and designs problem-solving behaviors (Hmelo-Silver & Barrows, 2008). Each problem cycle concludes with a reflection phase. PBL was selected as the TTPD approach with teachers in part, because prior research has proven effective both for teacher education (d = 0.64), and when participants are engaged in designing problems (d = 0.74) (Walker & Leary, 2009).

Table 2 shows key activities for the two TTPD designs, as well as data collection points. Note that participants in the *tech+PBL* TTPD design were asked to utilize PBL with their stud ents, only if they felt it aligned with their self-selected design problem, student needs, and their own educational philosophy. In contrast, participants in the *tech-only* TTPD design were asked to design activities using the IA in ways that aligned with their own educational philosophy.

Table 2

Key Activities for the Two TTPD Designs and Data Collection Points

Tech-only TTPD	*Tech+PBL* TTPD	Data collected
Workshop 1 (3 hours)		
(1) Take pre-survey (2) View example IA projects (3) Intro to online resources (4) Intro to IA: Walk through sample project creation (5) Participants select design problem (6) Individuals design IA project(s) (7) Discuss selection of quality of online resources (8) Review IA functionality	Same	Teacher pre-survey
Classroom implementation #1		
(1) Design and implement IA project(s) with students (2) Provide reflection paper on barriers and successes in implementation	Same	(1) Student pre-/post-questionnaire (2) PBL alignment of IA project (3) Web usage
Workshop 2 (3 hours)		
(1) Small then large group discuss implementation experiences (2) Review use of the IA, including advanced features (3) Design a new IA learning activity (4) Share ideas (5) Individuals begin to design new IA project(s)	(1) Small then large group discuss implementation experiences (2) Review use of the IA (3) Engage in inquiry-oriented activity (4) Large group inquiry-oriented discussion (5) Design own PBL learning activity (6) Share ideas (7) Individuals begin to design new IA project(s)	-
Classroom implementation #2		
(1) Design and implement new IA project(s) with students (2) Write reflection paper on barriers and successes	Same	(1) Student pre-/post-questionnaire (2) PBL alignment to IA project (3) Web usage
Workshop 3 (3 hours)		
(1) Small then large group discuss experiences: Technology (2) Review technical use of the IA, including advanced features	(1) Small then large group discuss experiences: Technology (2) Review technical use of the IA (3) Small then large group discuss PBL implementation experiences	Teacher post-survey

Methods

Participants

Classroom teachers from two adjacent school districts ($N = 18$) were assigned (based on scheduling preference) to one of two TTPD designs. In one design (*tech-only*), teachers ($N = 9$) solely learned technology skills to design activities for their students using online resources. In the other (*tech+PBL*), teachers ($N = 9$) learned technology skills to design specifical PBL activities for their students using online resources. Teachers were allowed to select one preferred classes in which to implement their design activities. Table 3 and Table 4 show the teacher and student demographics, respectively.

Teachers received one university course credit for completing all requirements.

Table 3

Teacher Demographics

Teacher demographic	*Tech-only* TTPD	*Tech+PBL* TTPD
# of teachers (% female)	9 (100%)	9 (88.9%)
Mean (standard deviation) of years in the current position	10.33 (6.22)	12.33 (9.90)

Table 4

Student Demographics

Characteristic		*Tech-only N* (%)	*Tech+PBL N* (%)
TTPD design		226 (67.87)	107 (32.13)
Ethnicity	White	164 (72.57)	84 (78.50)
	Hispanic/Latino	29 (12.83)	6 (5.61)
	Black or African American	1 (0.44)	0
	Other	6 (2.64)	1 (0.93)
	Two or more groups	7 (3.10)	7 (6.54)
	Did not answer	19 (8.40)	9 (8.41)
	English	193 (86.02)	101 (94.39)
Primary language	Spanish	19 (8.41)	5 (4.67)
	Bilingual	11 (4.87)	1 (0.93)
	Other	3 (1.32)	0

Data Sources

Table 2 shows TTPD activities and data collected at each phase.

Teacher survey. Teacher data were collected using an online survey at the beginning and end of the TTPD. The survey consisted of five Lickert scale (0 = “Strongly disagree”; 4 = “Strongly agree”) and eight open-ended items. Items were adapted from an established measure (Becker, 2000) of teacher knowledge, attitudes, and experience with respect to technology and teaching.

Table 5

Teacher Survey Sub-scales

Sub-scale	# of Lickert-scale item	Max. total points possible (0 = Low; 4 = High/item)	Reliability
Knowledge	2	8	0.89
Attitude	2	8	0.66
Experience	2	8	0.26

Responses on items for each sub-scale were summed. All teachers completed pre- and post- survey and *t*-tests of pre-test results showed no significant differences between groups ($p > 0.05$) for all of the subscales. In terms of reliability, teacher’s knowledge and attitude sub-scales showed high reliability while the reliability for the experience sub-scale was very low (see Table 5). Therefore, teacher experience was excluded from the further analysis and discussion.

Web usage data. Data of teachers’ use of the IA (Khoo, Pagano, Washington, Recker, Palmer, &

Donahue, 2008) were automatically collected by the IA system, including the number of IA logins, IA projects created, collected online resources used and student visits to IA projects.

PBL alignment of IA projects. In order to score alignment of IA projects with PBL, we developed a PBL rubric using items based on Walker and Shelton (2008). The rubric consisted of 14 elements in four categories (see Appendix). Three raters, randomly selected from a pool of five and blind to TTPD condition, independently scored the PBL alignment of teachers' IA projects. Each element's score ranged from 0 to 1 (0 = "Not present"; 1 = "Present"), for a maximum possible score of 14 points. The overall average one-way random effects ICC (intra-class correlation) (Shrout & Fleiss, 1979) was 0.83, which suggested an almost perfect agreement (Sim & Wright, 2005).

Student questionnaires. Students completed questionnaires before and after each of the two IA project implementations. As teachers taught different courses, an achievement test of student knowledge was not feasible. Instead, the student questionnaire contained self-report Likert-scale items addressing student knowledge, attitude and behavior.

Results

Results are organized by research questions. A variety of statistical testing was done, with a uniform alpha level of 0.05 for each test.

Research Question #1: Impact on Teachers

Impacts on teacher knowledge and attitudes in technology integration were assessed using the pre-/post-survey. Descriptive statistics and effect sizes (Cohen's *d*) of within-group gains are shown in Table 6.

Due to the small sample size, a Friedman analysis of variance test was conducted to compare the pre- and post- survey scores. Overall, teachers showed significant gains in knowledge, Friedman = 10.89, $p < 0.001$. There was no significant gain in teacher attitudes ($p = 0.48$). In part, this may be because participants reported higher attitudes on the pre-survey, and thus, had little room for improvement.

In terms of the group difference, a Friedman analysis of variance test was conducted to compare the gain scores between the TTPD designs. The result showed no group difference for either knowledge gain ($p = 0.51$) or attitude gain ($p = 0.51$), which may be a result of the relatively low statistical power and small n involved. When examining pre-/post- changes in terms of effect size, both TTPD design showed large gains for teacher knowledge. However, for teacher attitudes, the *tech-only* group showed a negative value, while the *tech+PBL* group showed a medium effect size.

Table 6

Teacher Self-report on Technology Integration Knowledge and Attitudes

		Pre-survey		Post-survey		Cohen's *d*
		Mean	*SD*	Mean	*SD*	
Tech-only ($N = 9$)	Knowledge using technology in classroom	5	1.87	7.22	1.20	1.45
	Attitude in teaching with technology	7.44	0.88	6.88	2.67	-0.32
Tech+PBL ($N = 9$)	Knowledge using technology in classroom	4.56	2.30	6.56	0.88	1.26
	Attitude in teaching with technology	6.44	1.33	7	1.12	0.46

Note. Possible values range from 0 = Low to 8 = High.

Research Question #2: Impact on IA Usage

Table 7 shows summary IA usage statistics for the two TTPD designs. Overall, usage is high, with high numbers of participant logins, IA projects created, and collected online resources used. Student usage also appears high, with high numbers of visits to the IA projects created by teachers, including one IA project accessed over 500 times. In short, these data suggest that the IA was successfully used by both teachers and students.

Table 7

The IA Usage Data (Six Months After the Completion of the TTPD)

		Mean	*SD*	Max.
Tech-only TTPD (*N* = 9)	# of participant logins to the IA	37.78	24.85	95
	# of IA projects created	9.22	3.23	14
	# of collected online resources used	36.67	31.50	114
	# of visits to non-private IA projects	150.44	137.77	423
Tech+PBL TTPD (*N* = 9)	# of participant logins to the IA	45.56	19.77	69
	# of IA projects created	14.67	6.60	26
	# of collected online resources used	70.22	37.72	141
	# of visits to IA projects	109.89	168.81	545

Research Question #3: Impact on Design

Table 8 shows results for teachers' IA projects PBL alignment scores. Note that PBL alignment results are likely an under-estimate of what happened in the classroom. Teachers may have asked students to use the IA project in groups, as an example, even though the IA project content did not make that clear. The means for all PBL scores are quite low, which may be the result of this underestimation, an overly strict measure, or may suggest that the PBL portion of the TTPD was not effective.

Table 8

IA Project PBL Alignment Scores

		Mean	*SD*	Max.
Tech-only TTPD (*N* = 9)	PBL score after workshop 1	0.22	0.67	2
	PBL score after workshop 2	0.55	1.33	4
Tech+PBL TTPD (*N* = 9)	PBL score after workshop 1	0.33	0.71	2
	PBL score after workshop 2	0.22	0.67	2

Note. Possible values range from 0 = Low to 14 = High.

Although scores were based on scales, a Mann-Whitney U test was run to account for the small sample sizes. Comparisons between different workshop treatments were not statistically different both after the first workshop ($p = 0.58$) and the second workshop ($p = 0.54$). In short, the TTPD did not change teachers' usage of PBL over time and both groups used consistently negligible levels of PBL in their IA projects. As noted, this may be a result of an overly stringent rubric.

Research Question #4: Validity and Reliability of Students Questionnaires

The ultimate test of the effectiveness of professional development is determining its links with student learning, although these links are likely to be indirect (Fishman, Marx, Best, & Tal, 2003). Our approach was to provide pre-/post- questionnaires to participants' students at the start and end of an activity using an IA project.

However, it is most necessary to determine if the measurement was valid and reliable.

Table 9

Student Survey Items Factor Analysis

Factor	Survey item	Factor loading
Factor 1: Student knowledge	I know enough to teach my friends about this topic	0.88
	I know a lot about this topic	0.88
Factor 2: Student attitude	If I got to decide what to do in class next I would pick this topic	0.89
	I like the topic the teacher has selected very much	0.88
Factor 3: Student behavior	I spend time outside of school learning about this topic	0.79
	I talk with my friends about this topic	0.76
	I talk to my parents about this topic	0.76

For the purposes of validity, a confirmatory factor analysis with varimax rotation showed three total factors (see Table 9). All were precisely aligned to the sub-scales as planned. Factor loading ranged from 0.76 to 0.89. Given the combination of a large sample size (N = 333) and the strength of factor loadings (Stevens, 1999), these data appear to be valid measures of student self-reports for behavior, knowledge, and attitude.

Table 10 provides details regarding the number of items whose responses were summed on the teacher survey for each of the constructs measured. Overall, questionnaire reliability was high (α = 0.79), as was each of the sub-scales.

Table 10

Pre-/Post- Student Questionnaire of Behavior, Knowledge, and Attitude Sub-scales

Sub-scale	# of Lickert-scale item	Max. total points possible (1= "Strongly disagree"; 5= "Strongly agree"/item)	Reliability
Student knowledge	2	10	0.80
Student attitude	2	10	0.71
Student behavior	3	15	0.73

Discussion and Conclusions

This article reported the impact of two design-oriented TTPD. Both showed high teacher and student usage of the tools and significant gains in teacher reported knowledge. Although both failed to improve teacher attitudes, this may be in part due to teachers' initially high levels of attitude leaving little room for improvement. When comparing the gain scores between TTPD groups, none of the TTPD design statistically outperformed the other on either the knowledge or attitude measures. However, in terms of the effect sizes, knowledge gain was large for both groups. For attitudes, the *tech+PBL* group showed a medium gain, while the *tech-only* group showed a negative gain.

Analyses of teachers' IA projects showed overall low usage of PBL elements, perhaps partially due to the fact that the use of PBL was optional. Furthermore, while the high inter-rater reliability evidence for the PBL alignment rubric is encouraging, the low scores of use of PBL elements show that measurement work remains. It is possible that PBL alignment scoring was not sensitive enough to differences within teacher-designed activities. For example, IA projects not only are needed to be cross-disciplinary, but also present cross-disciplinary problems to students, a rather high bar. As such, future work should consider refining the PBL rubric.

Finally, from a measurement perspective, the student self-report questionnaires proved to be both valid and reliable, as assessed by factor and reliability analyses for this sample. The measure is particularly noteworthy, because it was designed for and used with students learning a wide range of subject matter.

Limitations of the work include the non-experiment research design and the small number of participants. Another threat to internal validity may be cross-contamination. Teachers from two TTPD designs might have communicated between workshops, shared their experiences, thereby influencing each other. In terms of areas for future research, further analysis of the student data should be conducted to link teacher practice and student learning outcomes, as well as to compare the impact of different TTPD designs on classroom teaching and learning. The student questionnaire presented and evaluated in this article is an important step in this direction.

References

Angeli, C., & Valanides, N. (2005). Preservice teachers as ICT designers: An instructional design model based on an expanded view of pedagogical content knowledge. *Journal of Computer-Assisted Learning, 21*(4), 292-302.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*, 154-168.

Ainsworth, S., Honey, M., & Johnson, W. L. (2005). *Cyberinfrastructure for education and learning for the future: A vision and research agenda.* Washington, D. C.: Computing Research Association.

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education, 20*(6), 481-486.

Barrows, H. S., & Tamblyn, R. M. (1980). Problem-based learning: An approach to medical education. *Springer Series on Medical Education*. New York: Springer Publishing Company.

Becker, H. J. (2000). Findings from the teaching, learning, and computing survey: Is Larry Cuban right? *Education Policy Analysis Archives, 8*(51). Retrieved from http://epaa.asu.edu/ojs/article/view/442

Borgman, C., Abelson, H., Dirks, L., Johnson, R., Koedinger, K., Linn, M., … Szalay, A. (2008). *Fostering learning in the networked world: The cyberlearning opportunity and challenge, a 21st century agenda for the national science foundation* (p. 62). Arlington, V. A.: National Science Foundation, Report of the NSF Task Force on Cyberlearning. Retrieved from http://www.nsf.gov/pubs/2008/nsf08204/nsf08204.pdf

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3-15.

Brown, M., & Edelson, D. (2003). *Teaching as design: Can we better understand the ways in which teachers use materials so we can better design materials to support their change in practice?* (Design brief). Evanston, I. L.: Center for Learning Technologies in Urban Schools.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research on teaching.* Chicago: Rand McNally.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and teacher education, 19*(6), 643-658.

Hanson, K., & Carlson, B. (2005). *Effective access: Teachers' use of digital resources in STEM teaching.* Washington, D. C.: Gender, Diversities, and Technology Institute at Education Development Center, Inc. (EDC). Retrieved May 20, 2010, from http://www2.edc.org/gdi/publications_SR/EffectiveAccessReport.pdf

Hmelo-Silver, C. E., & Barrows, H. S. (2008). Facilitating collaborative knowledge building. *Cognition and Instruction, 26*(1), 48-94.

Khoo, M., Pagano, J., Washington, A. L., Recker, M., Palmer, B., & Donahue, R. A. (2008). Using web metrics to analyze digital libraries. Proceedings of *the 8th ACM/IEEE-CS Joint Conference on Digital libraries, JCDL '08* (pp. 375-384). New York: ACM.

Koehler, M., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152.

Koehler, M., & Mishra, P. (2008). *Introducing TPCK: Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3-30). New York: Routledge.

Kramer, B., Walker, A., & Brill, J. (2007). The underutilization of Internet and communication technology-assisted collaborative project-based learning among international educators: A delphi study. *Educational Technology Research and Development, 55*(5), 527-543.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77*(4), 575-614.

McArthur, D., & Zia, L. (2008). From NSDL 1.0 to NSDL 2.0: Towards a comprehensive cyberinfrastructure for teaching and learning (pp. 66-69). Presented at *the International Conference on Digital Libraries*. Pittsburgh, P. A.: ACM.

Means, B., Murphy, R., Javitz, H., Haertel, G., & Toyama, Y. (2004). *Design considerations for evaluating the effectiveness of technology-related teacher professional development.* Menlo Park, Calif.: SRI International.

Remillard, J. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *The Interdisciplinary Journal of Problem-Based Learning, 1*(1), 9-20.

Shrout, P., & Fleiss, J. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin, 86*(2), 420-428.

Sim, J., & Wright, C. C. (2005). The Kappa statistic in reliability studies: Use, interpretation, and sample size requirements. *Physical Therapy, 85*(3), 257-268.

Stevens, J. (1999). *Intermediate statistics: A modern approach.* Mahwah, N. J.: Lawrence Erlbaum.

Walker, A., & Leary, H. (2009). A problem-based learning meta analysis: Differences across problem types, implementation types, disciplines, and assessment levels. *Interdisciplinary Journal of Problem-Based Learning, 3*(1), 12-43.

Walker, A., & Shelton, B. (2008). Problem-based learning informed educational game design. *Journal of Interactive Learning Research, 19*(4), 663-684.

Wayne, A. J., Yoon, K. S., Zhu, P., Cronen, S., & Garet, M. S. (2008). Experimenting with teacher professional development: Motives and methods. *Educational Researcher, 37*(8), 469-479.

Appendix

Problem-Based Learning Alignment Rating Scale

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 and articles) that will assist in problem resolution.
Learner centered	Learners are prompted to utilize resources (content experts, reference books, journals and 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.