Educational Technology by Design: Results from a Survey Assessing its Effectiveness

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Abstract: We introduce *Technological Pedagogical Content Knowledge (TPCK)* as framework for thinking about what teachers need to know about technology, and argue for the role of authentic design-based activities in the development of this knowledge. We report data from a faculty development design seminar in which faculty members worked together with masters students to develop online courses. We developed and administered a survey that assessed the evolution of participants' learning, perceptions, and opinions about theoretical and practical knowledge about technology, and the growth of TPCK. Analyses of the changes between the beginning and end of the course indicate that the learning by design approach appears to be an effective instructional technique to develop deeper understandings of relationships between content, pedagogy and technology and the contexts in which they function.

Introduction

Recently, there has been an intense debate surrounding what teachers need to know (e.g., Handler & Strudler, 1997; Wise, 2000; Zhao & Conway, 2001; Zhao, 2003). There is, however, little clarity about what form this technological knowledge should take, and how it should be acquired. We offer one perspective that considers the development of *Technological Pedagogical Content Knowledge* (TPCK) within a *Learning by Design* seminar. Our approach towards technology integration values rich knowledge about how technology, pedagogy, and content interact with one another; as well as an understanding of the unique affordances of the *Learning by Design* approach to foster the development of these integrated knowledge structures. These ideas have been covered in greater depth elsewhere (Koehler & Mishra, in press; Koehler, Mishra, Hershey & Peruski, 2004; Koehler, Mishra, & Yahya, 2004; Koehler, Mishra, Yahya, & Yadav, 2004; Mishra & Koehler, 2003, in press a, in press b). However, because our rationale for conducting this study requires an understanding of these multiple (and interrelated) ideas, we use the following sections to broadly introduce these foundational strands before presenting a more in-depth and detailed explanation of the design experiment and our findings.

Introducing Technological Pedagogical Content Knowledge (TPCK)

Consistent with this situated view of educational technology we advocate increased attention to the complex interplay between technology, content, and pedagogy (Koehler, Mishra, Hershey, & Peruski, 2004; Mishra & Koehler, in press a, in press b, in press c). In our framework, we have built upon Shulman's (1987, 1986) work describing Pedagogical Content Knowledge, to highlight the importance of *Technological Pedagogical Content Knowledge* (TPCK) for understanding effective teaching with technology (see Mishra & Koehler, in press c for a more complete discussion of these issues). Our perspective is consistent with other approaches that have attempted to extend Shulman's idea of Pedagogical Content Knowledge (PCK) to the domain of technology (for instance see Hughes, in press; Keating & Evans, 2001; Lundeberg, Bergland, Klyczek, & Hoffman, 2003; Margerum-Leys, & Marx, 2002).

At the core of our framework (See Figure 1), there are three areas of knowledge: Content, Pedagogy and Technology.

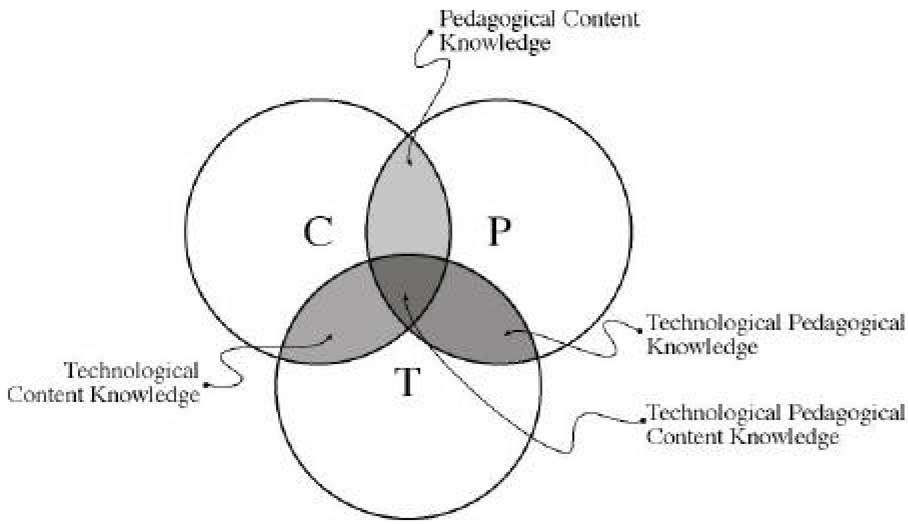

Figure 1: The TPCK framework

Content (C), is the subject matter that is to be learned/taught. High school mathematics, undergraduate poetry, 1st grade literacy, and 5th grade history are all examples of content that are different from one another.

Technology (T), encompasses modern technologies such as computers, the Internet, digital video, and more commonplace technologies including overhead projectors, blackboards, and books.

Pedagogy (P), describes the collected practices, processes, strategies, procedures, and methods of teaching and learning. It also includes knowledge about the aims of instruction, assessment, and student learning.

However, our approach goes beyond seeing C, P, and T as being useful constructs in and of themselves, and emphasizes the connections and interactions *between* these three elements. For instance, considering P and C together we get *Pedagogical Content Knowledge*, similar to Shulman's (1987) idea of knowledge of pedagogy that is applicable to the teaching of specific content. Similarly, there are constructs for *Technological Content Knowledge* (TC), and *Technological Pedagogical Knowledge* (TP). Finally, if we jointly consider all three elements (T, P, and C), we get *Technological Pedagogical Content Knowledge (TPCK)*. True technology integration, we argue, is understanding and negotiating the relationships between these three components of knowledge (Bruce & Levin, 1997; Dewey & Bentley, 1949; Rosenblatt, 1978). Good teaching is not simply adding technology to the existing teaching and content domain. Rather, the introduction of technology causes the representation of new concepts and relations in the multi-dimensional structure suggested by the TPCK framework.

Learning by Design

Developing TPCK requires teachers engaging in authentic problems of practice. Our learning technology by design approach, builds on ideas in project-based learning, problem-based learning, design-based learning, and constructivist approaches by emphasizing the value of authentic design problems for developing skillful teachers' reasoning about educational technology. For instance recent design-based seminars we have conducted have focused on the design of online courses. The participants in the design teams have to actively engage in inquiry, research and design, in collaborative groups (that include higher education faculty members and graduate students) to design tangible, meaningful artifacts (such as the website, syllabus and assignments for an online course) as end products of the learning process. Design is the anchor around which the class (and learning) happens. Therefore, every act of design is always a process of weaving together components of technology, content, and pedagogy. Moreover, the ill-structured nature of most authentic pedagogical problems ensures that there are multiple ways of interpreting and solving them. Thereby, teachers are more likely to encounter the complex and multiple ways in which technology, content, and pedagogy influence one another instead of thinking about rigid rules that imply simple cause-effect relationships between these components (Mishra, Spiro, & Feltovich, 1996).

Studying the development of TPCK

So far, we have offered an argument for considering the development of teachers' knowledge about technology in relationship to other forms of knowledge, mainly pedagogical knowledge and content knowledge. We have also offered design-based approaches as a means of helping teachers develop situated and nuanced understandings of the relationship between pedagogy, content and technology. However, these are not statements that have to be accepted at face value. Whether or not students develop TPCK is an empirical question and one that we have addressed in our research. The development of the TPCK framework has been part of a multi-year design experiment (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Design Based Research Collective, 2003), aimed at helping us understand teachers' development towards rich uses of technology (i.e. develop theory) while *simultaneously* helping teachers (both K-12 teachers and university faculty) develop their teaching with technology (i.e., inform practice).

Our earlier research publications have been broadly qualitative in nature. Though these approaches offer rich and detailed information about the phenomena (teacher knowledge around technology) these approaches are also time consuming and difficult to replicate. One of the ways we have sought to add quantitative evidence in support of the qualitative forms, is to develop a survey that captures essential elements of the learning by design process. This is the focus on this paper and it is described in greater detail below.

The design course context

We conducted this research within the context of a faculty development course taught by the second author during the spring semester of 2003. In this class, faculty members and graduate students worked collaboratively to develop online courses to be taught the following year. This particular instantiation of the "learning by design course" included four faculty members and fourteen students. The design task went beyond creating a website for the course and required the faculty members and students to work together to develop the syllabus, the course structure, the readings, student assignments, and assessment rubrics. They had to determine the nature of student interaction, how the course content would be offered and delivered, how technology would be used to accomplish course goals, and how the course website would be designed to make it fit with course content and pedagogy.

The design of the survey

We designed a survey that attempted to measure participants' attitudes, opinions, and learning in one of our design courses. The survey instrument we designed attempts to address three broad questions:

1. Students' perceptions of the learning environment (i.e. the learning by design approach).
2. The evolution in participant thinking regarding the course content. This is an important feature of the survey because an indicator of the success of the effort to design online courses should be changes in participants' thinking about teaching and learning online. In other words, evidence for the effectiveness of the learning by design approach may be found in changes in participants' thinking about the differences between face-to-face and online teaching. We would expect learners to start with somewhat simplistic ideas about moving from face-to-face to online teaching. However, we would also expect this to change with their participation in the learning by design course.
3. How participants were developing components of the TPCK framework over the course of the semester. Our previous research shows that participants' thinking about technology integration gets increasingly complex with time. However these previous studies focused on group learning (as opposed to individual learning). Our survey distinguishes between learning about TPCK at both the individual and the group level. The focus of this paper is on this aspect of the survey.

Method

Participants

Data for the present study comes from surveys completed by four faculty members (2 male and 2 female) and 13 students. One student in the class chose not to participate in the research. Participants agreed to allow artifacts created during the course to be used as research data following the completion of the course.

Procedure

As part of the course, participants completed an online survey four times during the course of the semester (week 1, week 4, week 8, and week 13 of the course). Completion of the surveys was a part of the course; part of students' grades were dependent on completing the surveys (but not on the content or quality of the answers).

Measures

Each survey consisted of 35 questions, and took less than 15 minutes to complete. Two questions were short answer (e.g., "Please write a short paragraph summarizing what is your role in the group"), and 33 questions used a 7-point Likert-Scale to rate the extent to which participants agreed or disagreed with statements about the course (e.g., "Our group has had to find different ways of teaching this content online"), where lower ratings indicated agreement with the statement, and higher ratings indicated disagreement. The content of each survey question is detailed in the results and discussion sections that follow.

Data analysis

In this paper, the results for the second and fourth administration of the survey were analyzed. Results were analyzed as matched-pair means (t-tests) for each of the 33 survey questions. For each pre-post difference, we also report P-values and Cohen's ? measure of practical significance for descriptive purposes. However, in order to control for overall experimental type-I error (because we conducted 33 comparisons), we also indicate which findings are significant if we set the experimental error rate at alpha = .05, using a sequential Holm procedure, so that the largest effect was tested at .05/33 (directional, 1-tailed test), the next effect was tested at .05/32, and so on.

Results

In pursuing the extent to which participants were learning about the categories of knowledge suggested by our TPCK framework, we designed several survey questions that asked participants to directly rate their engagement around these ideas, both at the level of the individual learner and at the design group level.

Question	**Week 4 (Ave & Std. Dev)**	**Week 13 (Ave & Std. Dev)**	**Matched-Pair t (df=14)**	**p-value**	**Cohen's ?**
T1– I am learning a lot of practical technology skills that I can use	5.20 (1.27)	2.93 (1.39)	4.35	< .01[=]	1.77
T2 – I am thinking more critically about technology than before	5.13 (1.73)	2.33 (1.29)	4.29	< .01[=]	1.90
C – I have been thinking and working a lot of the course content	4.93 (1.62)	2.87 (1.69)	2.66	= .019	1.29
P – I have been thinking and working a lot on the pedagogy of the course we are designing	5.47 (1.51)	2.73 (1.49)	3.76	< .01[=]	1.89
T3 – I have been thinking and working a lot on the technology of the course we are designing	5.07 (1.39)	2.87 (1.69)	3.01	< .01	1.48

[=]The change between Week 4 and Week 13 is statistically significant, using an overall experimental error-rate of alpha=.05, using a sequential Holm procedure.

Table 1: Individual's perceptions of content, pedagogy, and technology.

Five questions were helpful in assessing individual's engagement with categories suggested by our framework (see Table 1). Overall, participants' initially tend to disagree that they are thinking differently about technology, and they also do not feel as though they are learning technology skills (questions T2 and T1). They have difficulty designating themselves as working on technology, content, or pedagogy of the course they are designing (questions C, P, and T3).

Here the group trend probably doesn't characterize individuals very well – when asked to report their roles in the course, some clearly state their role is "tech guru" or "developing content." Likewise, the standard deviations of the ratings are among the largest observed in this study. We take this to mean that there is great variety as to what individuals are thinking about in any given group. However, overall (as in average rating), there does not seem to be an initial, uniform, high degree of engagement in any of the three main categories of knowledge (technology, content, or pedagogy).

There is a statistically (and practically) significant shift that occurred over the timeframe of the course (Table 1). By the end of the semester, participants are much more likely to indicate thinking in each of the three categories of knowledge (content, pedagogy, and technology) and report that they are thinking about technology rather differently. They are also more able to see concrete skills that they have learned along the way. We take this as indication that individuals are, necessarily, thinking about each knowledge category (and their relationships), rather than just solely identifying with just one area of knowledge (e.g., "tech guru").

Similar patterns are suggested at the level of group analysis. The TPCK framework suggests there are many components of knowledge associated with thinking about technology in education: Content Knowledge (C), Pedagogical Knowledge (P), Technology Knowledge (T), Technological Content Knowledge (TC), Pedagogical Technology Knowledge (PT), Pedagogical Content Knowledge (PC), and Technological Pedagogical Content Knowledge (TPC). Using these 7 knowledge components, we designed one question to assess the extent to which participants thought their group was grappling with each knowledge category (See Table 2).

Question	**Week 4 (Ave & Std. Dev)**	**Week 13 (Ave & Std. Dev)**	**Matched-Pair t (df=14)**	**p-value**	**Cohen's ?**
(C) - Our group has been thinking and talking about the course content	5.73 (1.16)	2.13 (1.25)	6.44	< .001[=]	3.09
(P) – Our group has been thinking and talking course pedagogy	5.80 (1.01)	2.20 (1.08)	6.87	< .001[=]	3.55
(T) – Our group has been thinking and talking about technology	6.00 (0.93)	2.27 (1.22)	7.44	< .001[=]	3.58
(CP) – Our group has been considering how course content and pedagogy influence one another	5.53 (0.99)	2.33 (1.35)	6.29	< .001[=]	2.80
(PT) – Our group has been considering how course pedagogy and technology influence one another	5.60 (0.91)	2.13 (0.99)	8.65	< .001[=]	3.77
(CT) – Our group has been considering how technology and course content influence one another	5.47 (1.06)	2.07 (1.03)	8.04	< .001[=]	3.36
(TPCK) – Our group has chosen technologies to fit our course content and the faculty member's teaching philosophy	6.00 (1.00)	1.93 (1.03)	8.43	< .001[=]	4.10

[=]The change between Week 4 and Week 13 is statistically significant, using an overall experimental error-rate of alpha=.05, using a sequential Holm procedure.

Table 2: Group involvement in content, pedagogy, and technology, and the components of the TPCK framework

Initially, participants perceived little grappling with issues in any of these categories. We are somewhat surprised by the low ratings on technology – it has been our impression that early discussions are dominated by technology, since it is the new ingredient that is being considered in the design of their course. Perhaps they don't see these discussions as deep, or worth reporting. Regardless, it would seem that at the early stages, the move to online teaching is not forcing participants to think about how technology and pedagogy, for example, are related.

The picture by the end of the course, is again considerably different (Table 2). There are large statistical, and "very large" practical changes on every category of knowledge in the TPCK framework. According to these results then, it would seem that the design approach in general, or the task of developing an online course in particular, is well suited to developing knowledge across the spectrum of reasoning suggested by the TPCK framework.

Conclusion

Developing Technological Pedagogical Content Knowledge (TPCK) requires teachers to engage with technology, pedagogy and content in contexts that honor the rich connections between them. The learning technology by design approach described above is one approach that explicitly foregrounds these inter-relationships. The research presented in this paper shows that when offered such learning contexts, participants move from considering technology, pedagogy and content as being independent of each other, to a more complex and dialogic view of the web of relationships between content, pedagogy and technology and the contexts within which they function. In other words participation in the design activities led to the development of TPCK.

This paper makes multiple contributions to the fields of teacher knowledge and educational technology. First, this paper extends our theoretical work on teacher knowledge (the TPCK framework) and offers it further empirical support. Second, it operationalizes the theoretical ideas of TPCK and instantiates them in a survey questionnaire. We see this survey as being a useful tool for future research on the nature and development of TPCK. Finally, this paper emphasizes the pedagogical value of learning by design seminars and explains how TPCK develops through group activity.

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