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Transforming a teacher education method course through technology: effects on preservice teachers' technology competency

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Abstract

In this study, an instructional design model was employed for restructuring a teacher education course with technology. The model was applied in a science education method course, which was offered in two different but consecutive semesters with a total enrollment of 111 students in the fall semester and 116 students in the spring semester. Using tools, such as multimedia authoring tools in the fall semester and modeling software in the spring semester, teacher educators designed high quality technology-infused lessons for science and, thereafter, modeled them in classroom for preservice teachers. An assessment instrument was constructed to assess preservice teachers' technology competency, which was measured in terms of four aspects, namely, (a) selection of appropriate science topics to be taught with technology, (b) use of appropriate technology-supported representations and transformations for science content, (c) use of technology to support teaching strategies, and (d) integration of computer activities with appropriate inquiry-based pedagogy in the science classroom. The results of a MANOVA showed that preservice teachers in the Modeling group outperformed preservice teachers' overall performance in the Multimedia group, $F = 21.534$, $p = 0.000$. More specifically, the Modeling group outperformed the Multimedia group on only two of the four aspects of technology competency, namely, use of technology to support teaching strategies and integration of computer activities with appropriate pedagogy in the classroom, $F = 59.893$, $p = 0.000$, and $F = 10.943$, $p = 0.001$ respectively. The results indicate that the task of preparing preservice teachers to become technology competent is difficult and requires many efforts for providing them with ample of

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opportunities during their education to develop the competencies needed to be able to teach with technology.

Keywords: Elementary education; Media in education; Improving classroom teaching; Interactive learning environments; Learning communities

1. Introduction

As the student/computer ratio in schools is getting smaller and smaller, more concerns are raised about the preparedness of K-12 teachers to appropriately integrate technology in teaching and learning. According to a report of the National Center for Education Statistics (2000), only 44% of new teachers (with three years of classroom experience or less) feel well prepared to infuse technology in teaching. Current statistics also indicate that less than 15% of all teachers in the United States use computers in their teaching, and teachers in general do not seem to be taking advantage of the computer's potential (Becker, 1999; Bosch, 1993; Bruder, 1993). More importantly, several researchers (e.g., Pope, Hare, & Howard, 2002; Selinger, 2001; Wang & Holthaus, 1999; Willis & Mehlinger, 1996) have found in their studies that preservice teacher education does not adequately prepare future teachers to teach with technology.

Recent calls for educational reform in teacher education stress the need for innovative teacher education restructuring to ensure that preservice teachers not only understand how to use a computer but also how to design high quality technology-enhanced lessons (Brush et al., 2003; Dawson, Pringle, & Adams, 2003; Ertmer, 2003; International Society for Technology in Education, 2002; National Council for Accreditation of Teacher Education, 1997; Thomas, 1999; Thompson, Schmidt, & Davis, 2003; Watson, 2001; Wilson, 2003). International Society for Technology in Education (2002) has taken a critical step in showing the way to technology integration by providing a set of standards describing technology competencies for inservice and preservice teachers. Peck, Augustine, and Popp (2003) argue, however, that teacher educators need detailed and explicit guidance in order to be able to redesign their method courses effectively. A preferred approach for restructuring teacher education courses with technology has been to infuse technology in method courses (e.g., Davis & Falba, 2002; Guy & Li, 2002), because method courses provide a meaningful context within which the integration of technology can be pedagogically situated in the teaching of subject matter. Thus, as Ertmer (2003) states, we need to become more specific and explicit about the types of technology-supported lessons that teacher educators design, and, in particular, which technology is being infused or integrated to support learning.

Derry and Lesgold (1996) argue that improved instructional designs should move away from the behavioral-objectivist approaches and consider the authentic context where the activity will take place, as well as the community of practice learners should be asked to participate. For the teaching of science, according to the American Association for the Advancement of Science (1993) and the National Research Council (1996), visions for a complete science education community of practice should involve a commitment to the inclusion of technology as a tool for learning both science content and science processes. Some researchers (Pedersen & Yerrick, 2000) acknowledge that "teacher education programs bear a large part of the responsibility to rear teachers prepared to use technology, especially computers, in line with current science education visions'' (p. 145). The National Science Education Standards (National Research Council, 1996) call for science educators to act as facilitators of student inquiry. The recommendations ask science educators to integrate appropriate technology for the purpose of engaging students in inquiry and in a process of constructing authentic scientific knowledge. Drawing from the writings of Roth (1996) and Roth and Loucas (1997), authentic scientific knowledge is regarded to be empirically based, contextually situated, and influenced by the activity, context, and culture in which it is used. Thus, the construction of authentic science is embedded in webs of social relations, and it is not generated in a full-proof laboratory. Consequently, ''...it is subjective, and thus, not value-free, probabilistic in nature, and temporarily valid, or certain, as the accumulation of new evidence may lead us to reject or modify any theory that was previously accepted'' (Valanides, 2003, p. 43). This seems to imply that as long as classroom instruction continues to portray science as memorization and retrieval of information, the infusion of technology into classrooms will never instigate any real change. On the contrary, teachers should ''encourage and model the skills of scientific inquiry as well as the curiosity and openness to new ideas and data, and skepticism that characterizes science'' (National Research Council, 1996, p. 145). An inquiry-based approach to science teaching and learning aims at engaging learners in activities in which they can exchange perspectives about what constitutes scientific knowledge, and challenge their epistemological beliefs about science. How is technology integrated in such environments? Which computer software are appropriate to be used? What might it mean to know how to teach and learn with technology within a specific discipline such as science?

In an attempt to provide explicit guidance to teacher educators about how to redesign their method courses with technology, I discuss, in this paper, how an Instructional Systems Design (ISD) model was used to transform a science education method course with multimedia and modeling tools, and report on findings related to the effects on preservice teachers' technology competency in designing technology-enhanced learning for elementary school children.

2. An ISD model for transforming teacher education method courses with technology

The ISD model, shown in Fig. 1, was designed to assist teacher educators restructure method courses with technology, so that student teachers experience the value of technology in teaching and learning. Ultimately, the goal is, through these redesigned learning environments, to prepare preservice teachers become technologically or IT competent, that is, able to use the computer as a learning tool for enhancing their teaching practices, and not just as a delivery vehicle for supporting old ones.

The ISD model in Fig. 1 diverges from traditional ISD models in various ways. As it is widely accepted, the field of instructional technology is filled with ISD models. For the most part, these models are prescriptive, and offer structured guidelines and procedures for instructional designers (e.g., Dick & Carey, 1985; Gagne & Briggs, 1979). A typical ISD model is divided into five stages, namely, analysis, design, production/development, implementation, and revision (Bagdonis & Salisbury, 1994). In some cases, ISD models are presented in the form of frameworks, such as the one presented by Seels and Richey (1994), describing the five domains of the field, which they are referred to as design, development, utilization, management, and evaluation. In addition, it is

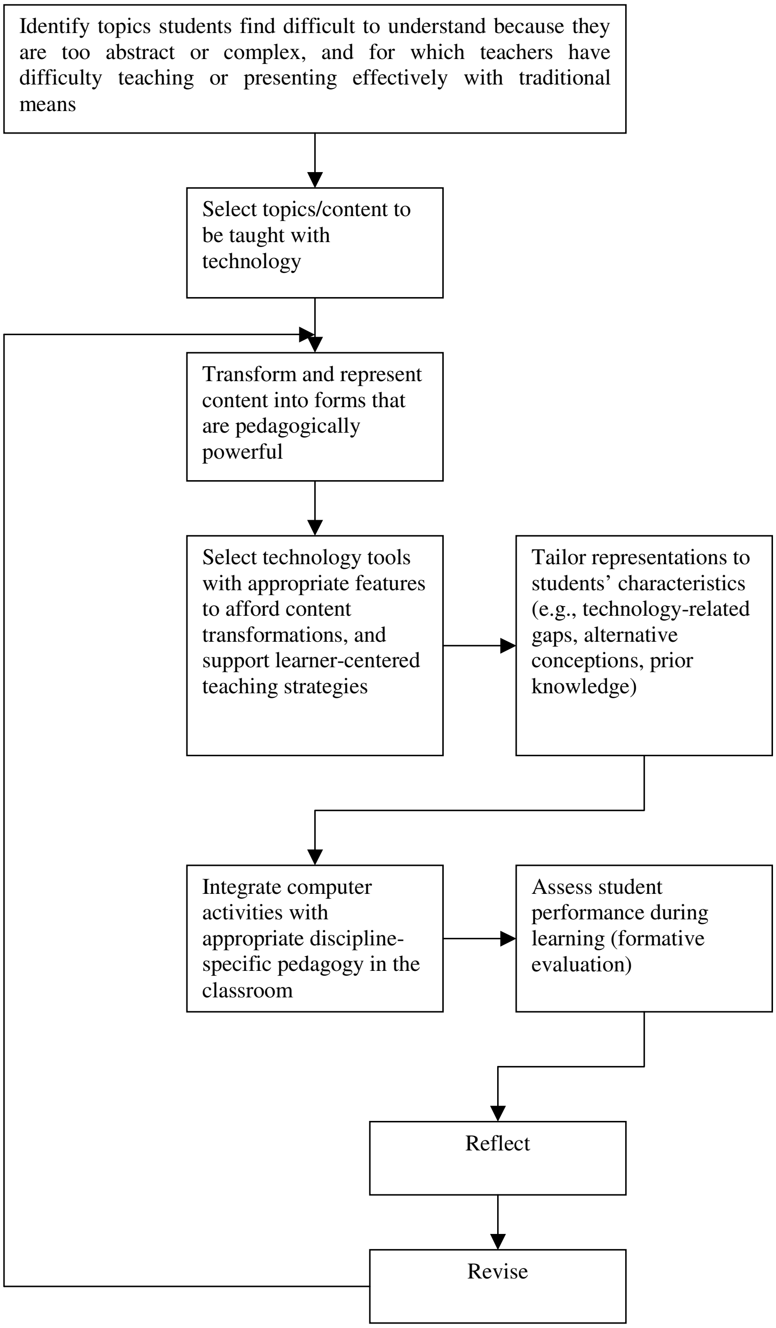

Fig. 1. An ISD model for integrating technology in method courses.

also accepted that the practice of instructional design generally reflects a behavioral-objectivist approach to designing instruction. This means that the instructional design process (a) is sequential, linear and systematic, and begins from a precise plan of action including clear behavioral objectives, (b) breaks down complex tasks into simpler sub-components that need to be taught first, (c) emphasizes the delivery of pre-selected facts favoring direct methods of instruction, such as drill and practice, and tutorials, and (d) invests most of the assessment effort in summative evaluations to prove whether the instruction worked or not – although formative evaluation has also been an important part of more recent ISD models (e.g., Dick & Carey, 1990; Leshin, Pollock, & Reigeluth, 1992). There have been reactions to the traditional ISD process (e.g., Duffy & Jonassen, 1992), and one of them has been the situated cognition view. This view is based on the notion that all knowledge is fundamentally situated in the environment within which it has been acquired (Derry & Lesgold, 1996). The implications of the situated cognition view for instructional design is that it is impossible outside a community of practice to capture the true complexity of tasks with traditional task analysis. Wenger (1990), for example, has documented numerous instances of misalignment between what was taught, and what was actually practiced within a working community of practice. Moreover, as Derry and Lesgold (1996) argue, authentic cognitive activity is socially situated, and cognitive apprenticeship constitutes an important part of it (Collins, Brown, & Newman, 1989). Cognitive apprenticeship refers to shared problem-solving activities between mentors, such as a teacher, a student with greater experience or a coworker, and novices. According to the cognitive apprenticeship views of learning, "in the early stages of learning, good mentors provide overall direction and encouragement, but assume only that portion of the task that is currently too advanced for novices to manage alone. As novices' performance improves, the mentor gradually fades support, encouraging novices to work and think more independently" (Derry & Lesgold, 1996, p. 792).

The model in Fig. 1 diverges from the traditional ISD approach, and is more in agreement with the situated cognition view. The model is applicable or transferable to different disciplines, and aims at aligning content, pedagogy, and technology as these relate to a specific discipline. It has been constructed based on insights from years of experience with training K-12 teachers integrate computer-based technologies in their classrooms. Based on these experiences, teachers' two main concerns with technology are (a) how technology can help them teach topics that they find hard to teach or present due to their abstractness or complexity, and (b) how technology will be integrated in the classroom. These concerns have also been documented in the literature with the ACOT project (Sandholtz, Ringstaff, & Dwyer, 1997), the PT3 studies (Mullen, 2001), and the many other efforts researchers are undertaking in transforming their teacher education programs.

In this study, the ISD model was applied in the discipline of science education and aimed at *aligning* science content with inquiry-based pedagogy and appropriate technology tools with inherent features that could afford science content transformations, such as making scientific concepts more accessible through visualization, modeling, and multiple external representations (American Association for the Advancement of Science, 1993; Gordon & Pea, 1995).

Based on the model in Fig. 1, the process of restructuring science education method courses with technology begins with identifying topics that students find difficult to understand or topics that science teachers find difficult to teach. After the identification of topics to be taught with technology, the content is transformed or represented into forms that are pedagogically powerful, so that the content becomes more accessible or understandable to learners. Thereafter, appropriate technology tools and specific teaching strategies that can afford the desired content transformations/representations are selected, and computer activities are integrated in the classroom with appropriate pedagogy, such as inquiry-based pedagogy. Before integration, representations are tailored to students' specific characteristics, such as prior knowledge, preconceptions, and technology gaps related to lack of strong computing skills. During learning, formative assessment takes place as an ongoing process to ''capture important learning goals and processes, and to more directly connect assessment to on going instruction'' (Shepard, 2000, p. 5). Moreover, as Shepard (2000) states, when assessment is dynamic and occurs concurrently with learning, it allows teachers to provide assistance as part of assessment and provides them with insights of how to scaffold the next steps. Finally, the ISD process concludes with reflection and revision.

3. Methodology

3.1. The context of the study

In this study, I report on findings from four sections of the same third-year science-education method course, which took place during the academic year of 2002–2003. Two of the sections occurred in the fall semester of 2002 with a total enrollment of 111 elementary student teachers and involved the integration of multimedia authoring tools. The other two sections occurred in the spring semester of 2003 with a total enrollment of 116 elementary student teachers and involved the integration of modeling software. Participants were elementary third-year student teachers who were randomly assigned in the four sections of the course. Prior to taking this method course, student teachers completed during their freshman and sophomore years two basic computing courses in which they learned Word, Excel, PowerPoint, Internet, and Hyperstudio. The purpose of the two courses was to mainly raise student teachers' skill proficiency level, so that they become competent in utilizing the tools on a personal level for the purpose of improving their productivity, and not as tools for designing technology-enhanced learning for elementary school children. In addition, none of the student teachers had any prior experience related to either designing lessons with multimedia or modeling software.

In all sections, the ISD model shown in Fig. 1 was employed to design technology-infused lessons and activities for science and, thereafter, model them in class. In addition, student teachers were asked to design their own technology-enhanced lessons for teaching science and present them in class. In particular, student teachers were guided to first identify, either through experts or by reading the literature, scientific concepts or areas from the elementary science curriculum that students find difficult to understand and teachers difficult to present or teach. Subsequently, they were asked to think about the *alignment between technology, the content to be taught, and inquiry-based teaching*, so that they could understand how technology can become a means in an inquiry-based science classroom for effectively transforming abstract science content into more concrete or realistic forms. Thus, students had plenty of opportunities throughout the semester to observe and study the structure and process of designing and developing technology-infused lessons for science, as well as practice the use of technology in science teaching before they designed their own lessons.

3.2. The use of ICT tools in science teaching

Papert's (1993) notion of constructionism asserts that students should be given opportunities to construct artifacts, so they make visible to others the kind of knowledge construction that they do in their heads. Moreover, as Dede (1994) states, hypermedia tools offer new methods for structured discovery, address varied learning styles, are motivating and empower students, and allow educators to present information as a web of interconnections rather than a stream of facts. The integration of such tools in science method courses allows students to become designers of instruction and engage them in a process of inquiry learning. In this process, they are guided to (a) collect, access, assess, and integrate sources of appropriate information, and (b) structure multiple pathways through information (Erickson & Lehrer, 2000). Later on, these artifacts can be showcased so that students can see others' work, share perspectives, and engage in constructive dialogue about their artifacts and how these represent alternative conceptual understandings of scientific concepts.

In the two sections of the course, which took place in the fall of 2002, the integration of multimedia tools was modeled in the teaching of science with a series of technology-infused lessons using well-known multimedia authoring tools, such as Hyperstudio and Multimedia Builder. According to Ertmer (2003), as well as cognitive apprenticeship views about learning (Collins et al., 1989), modeling technology-infused lessons can be a beneficial strategy for teacher educators to use, as it can provide future teachers with important information about how to complete a complex task, such as a design task, and increase their confidence by observing how an expert deals with the complexity of the design task. After modeling a series of technology-infused lessons in class, student teachers were asked to create their own technology-infused lessons, while assistance on how to use the tools was provided as needed. Specifically, each student teacher was asked to (a) choose a topic from the elementary science curriculum that learners have difficulty in understanding, or teachers have difficulty in teaching or presenting, (b) search the Web and evaluate Websites suitable for teaching this topic, (c) use materials found on the Web to develop computer-based activities using Hyperstudio or Multimedia Builder, and (d) integrate computer-based activities in an 80-min technology-enhanced lesson for elementary school children to be taught in a school classroom with other planned activities. In addition, student teachers were guided to design their lessons based on constructivist principles of learning theories, which view the learner as the active constructor of knowledge.

In the other two sections of the course, which took place in the spring semester of 2003, the integration of ModellingSpace was also modeled in the teaching of science. The construction of models, static and or dynamic, are extremely important for the mediation of conceptual understanding of abstract science concepts. A model is an object, a drawing, a diagram, or some other means of representing something, which cannot be directly observed. Using models to show and explain conceptual understanding elicits a wide range of higher order thinking skills, such as analyzing, evaluating, reasoning, problem solving, and decision making (Jonassen, 2000). Computers have the capability to permit models to become interactive and amenable to a student's manipulation.

A number of tools can be used for developing mental representations of the phenomena students study and for allowing students to represent their ideas visually (Gordon & Pea, 1995). Computer modeling tools enable students to visually explore the meaning of abstract concepts, and, thus, to clarify and correct alternative conceptions of scientific phenomena. Computer programs can be used to model qualitatively the behavior of complex systems and processes. Thus, they are essential tools for facilitating learners' qualitative understanding of how things in science work and why they work the way they do (National Research Council, 1996; Penner, 2000/2001).

In this study, a computer-modeling tool, namely ModellingSpace (Dimitrakopoulou & Komis, in press), was used to create and test qualitative and quantitative computer models without any programming. Using ModellingSpace, the user first creates objects, which relate to the entities of the scientific system under investigation, such as plant, sun, ground, and so on. The system allows a user to associate an icon with each object, so that it is visually associated with what it actually represents. Then, the user associates variable quantities with each object, called factors, which define measurable characteristics of an object, such as growth, light, volume, etc. Finally, factors are designated as causal or affected depending upon the direction of the relationship between them. ModellingSpace supports both qualitative and quantitative relationships. After the creation of a model, the user may test or run it, from the beginning to the end without any interruption, or step by step.

The use of ModellingSpace in the teaching of science was systematically modeled in a series of sessions where the importance of modeling in science was discussed in depth, and, through examples, the process someone goes through to create a model was explicitly taught. Moreover, students attended workshops where the software was demonstrated, and where it was also discussed how to infuse the software in the classroom with a variety of lesson plans and activities. For the rest of the semester, the emphasis was given on those areas of the elementary science curriculum where students had (mis)conceptions or alternative conceptions, as these had been identified during the course. Specifically, it was discussed how ModellingSpace could be used in an inquiry-based classroom learning environment to create interactive models to assist students in a process of testing hypotheses and controlling variables for the purpose of correcting their (mis)conceptions or alternative conceptions. In addition, as it was the case with the student teachers in the multimedia sections, student teachers in the modeling software sections were also asked to design their own technology-infused lessons with ModellingSpace and present them in class following the same guidelines that student teachers in the multimedia sections followed. A comparison of the Multimedia and Modeling groups is shown in Table 1.

Table 1
Comparison of the treatments in the Multimedia and Modeling groups

Multimedia group	Modeling group
Tools used: Hyperstudio and Multimedia Builder	Tools used: ModellingSpace
The instructor modeled a series of technology-infused lessons using Hyperstudio and Multimedia Builder	The instructor modeled a series of technology-infused lessons using ModellingSpace
Student teachers were assisted with learning how to use Hyperstudio and Multimedia Builder	Student teachers were assisted with learning how to use ModellingSpace
Student teachers were asked to design their own technology-infused lessons using Hyperstudio and Multimedia Builder	Student teachers were asked to design their own technology-infused lessons using ModellingSpace
Student teachers were guided to design their 80-min lessons based on constructivist principles	Student teachers were guided to design their 80-min lessons based on constructivist principles
Student teachers presented their technology-infused lessons in class	Student teachers presented their technology-infused lessons in class

Table 2
Instrument for assessing student teachers' technology competency

The learner selected an appropriate science topic to be taught with technology	The learner did not select an appropriate science topic to be taught with technology
The learner used appropriate technology-supported representations to transform the content	The learner did not use appropriate technology-supported representations to transform the content
The learner used technology to support teaching strategies	The learner did not use technology to support teaching strategies
The learner integrated computer activities with appropriate pedagogy in classroom instruction	The learner did not integrate computer activities with appropriate pedagogy in classroom instruction

3.3. Assessment instrument

Student teachers' technology-infused lessons constituted the unit of analysis. For analysis purposes, the 111 student teachers in the sections with the multimedia authoring tools will be regarded as the Multimedia group, and the 116 student teachers in the sections with the modeling software will be regarded as the Modeling group. An assessment instrument was constructed inductively using the constant comparative analysis method (Glaser & Strauss, 1967; Strauss & Corbin, 1990) to assess students' technology-infused lessons. Succinctly, the goal of the constant comparative method is to classify a participant's answer into an appropriate level. Initially, each answer is coded into as many levels of analysis as possible. Gradually, as each answer is constantly compared with all other answers the levels of the rubric as well as the properties of each level start to develop. The instrument is shown in Table 2.

Based on the instrument, technology competency is defined in terms of four dimensions, namely, (a) selection of appropriate science topics to be taught with technology, (b) use of appropriate technology-supported representations and transformations of science content, (c) use of technology to support teaching strategies, and (d) integration of computer activities with appropriate inquiry-based pedagogy in the science classroom. Each dimension was assessed using a two-rating scale – one or zero. A score of one indicated success in satisfying a specific dimension of the assessment instrument, and a score of zero indicated failure to do so. A cumulative score (0–4) was also calculated to assess student teachers' overall performance. Two independent raters, a doctoral student in science education and an expert in instructional technology, evaluated all lesson plans and activities based on the above criteria, and a Pearson r between the two ratings was found to be 0.91. The two raters and the researcher discussed the observed disagreements between the two raters and resolved after discussion the existing differences.

4. Results

Table 3 shows descriptive statistics on each aspect of student teachers' technology competency. Specifically, student teachers in the Modeling group reported a higher competency in three of the four aspects of the dependent variable, namely, use of appropriate technology-supported

Table 3
Descriptive statistics of student teachers' technology competency (n = 227)

Dimensions of technology competency	Group	M	SD	n
1. Selection of appropriate science topics to be taught with technology	Multimedia	0.91	0.288	111
	modeling	0.92	0.269	116
2. Use of appropriate technology-supported representations to transform science content	Multimedia	0.68	0.467	111
	modeling	0.78	0.419	116
3. Use of technology to support teaching strategies	Multimedia	0.17	0.378	111
	modeling	0.62	0.487	116
4. Integration of computer activities with appropriate pedagogy in classroom instruction	Multimedia	0.14	0.353	111
	modeling	0.33	0.471	116
5. Total technology competency	Multimedia	2.91	1.092	111
	modeling	3.65	1.287	116

representations to transform science content, use of technology to support teaching strategies, and integration of computer activities with appropriate pedagogy in classroom instruction. Both groups performed almost the same on the first aspect of the dependent variable, namely, selection of appropriate science topics to be taught with technology. A multivariate ANOVA (MANOVA), using the four ratings of technology competency and the total performance as the dependent variables, was subsequently conducted. The results indicated that the ratings on the total technology competency between the two groups were statistically significant, $F = 21.534$, $p = 0.000$. The ratings on use of technology to support teaching strategies, and integration of computer activities with appropriate pedagogy in classroom instruction were also statistically significant, $F = 59.893$, $p = 0.000$, and $F = 10.943$, $p = 0.001$, respectively. The ratings on selection of appropriate science topics to be taught with technology, and use of appropriate technology-supported representations to transform science content were not statistically significant between the two groups.

The results showed that the majority of student teachers in both groups selected appropriate science topics to be taught with technology, but they did not always use the features of the tools appropriately to transform science content. For example, student teachers in the Multimedia group used the tools mostly to show pictures to students as well as to deliver scientific facts and textbook information to learners. Thus, even though, they used the tools to transform the content using various multimedia forms, those forms were not always pedagogically powerful. Student teachers in the Modeling group also used the tool to transform the content, but they tended to oversimplify the model or phenomenon, under investigation, without bearing in mind the distinct added value and the potential of modeling tools in making complex phenomena easier to comprehend. Thus, there were not any significant differences between the two groups on the first two aspects of technology competency.

The findings also indicated that student teachers in the Modeling group reported a statistically significant higher technology competency in designing interactive learning activities with technology, and thereafter integrating them with appropriate inquiry-based pedagogy in classroom instruction. This signifies that ModellingSpace, the modeling software that was used in the study, had a significant effect on student teachers' understanding of the pedagogical uses of modeling software in the classroom and how it can become part of learning. Thus, student teachers effectively used ModellingSpace to create models that learners could interact with to study the behavior and interrelationships of complex scientific systems. Nevertheless, not all student teachers recommended learner-centered/interactive integration approaches, where learners worked collaboratively in groups to interact with a model, test hypotheses by controlling variables, and thereafter revise it appropriately.

The results obtained from the student teachers in the Multimedia group also indicated that they did not understand the multitude of ways in which multimedia authoring tools can potentially shape the teaching and learning process. Specifically, student teachers in the Multimedia group, contrary to the Modeling group, failed to identify a set of teaching strategies that multimedia tools could support to make the science classroom environment more inquiry-centered as well as student-directed. In addition, they rarely integrated their computer activities with inquiry-based pedagogy in the classroom, and simply used the activities to support traditional teacher-centered practices. For example, they envisioned a classroom environment in which the teacher used multimedia tools to present information to students or envisioned a learning environment in which students used the teacher-made "multimedia presentations" to simply read and become informed about a topic.

5. Discussion and implications

The main question that was investigated in the study was the extent to which restructuring a science education method course with either multimedia or modeling tools, using the same ISD model, would affect student teachers' technology competency in designing high quality technology-supported learning for elementary school children. The results indicated that:

- Student teachers in the Modeling group significantly outperformed student teachers in the Multimedia group on total technology competency, use of technology to support learner-centered teaching strategies, and integration of computer activities with appropriate inquiry-based pedagogy in science classroom instruction.
- There was not a statistically significant difference between the Multimedia and Modeling groups on selection of appropriate science topics to be taught with technology, or use of appropriate technology-supported representations to transform science content.

More specifically, student teachers in the Multimedia group mostly used the multimedia authoring tools as delivery vehicles to electronically present information to learners, and did not use the tools to either support learner-centered strategies or integrate computer activities in the classroom with appropriate pedagogy. In essence, the multimedia authoring tools were mostly used to support teacher-centered practices and not as tools with added value in learning, while this tendency was less obvious in the Modeling group.

The results can be attributed to several reasons related to the scaffolds afforded by the tools as well as the difficulties student teachers encountered with learning to use the tools. The multimedia authoring tools that were used in the study are open software systems that can be used for the teaching of any content domain, not just science. It seems that student teachers had difficulty with aligning the unique features or affordances of the tools with appropriate pedagogy for teaching science content. The modeling software, although open software as well, has a built-in interface which scaffolds the construction of computer models. Thus, the affordances of the tool scaffolded student teachers' thinking of how to create interactive computer models for testing out hypotheses and controlling variables. Moreover, personal experience from the study corroborates research evidence (e.g., Chandler & Sweller, 1996; Wedman & Diggs, 2001; Woodrow, 1991) indicating that student teachers frequently face difficulties with learning how to use technology tools. Due to these skills-related difficulties, the instructors of the course had to provide training sessions for demonstrating the different software to student teachers, and often technology itself turned out to be the point of instruction and not the role that technology can have in designing technology-enhanced learning environments. Thus, it could be the case that student teachers felt so caught up in learning how to use the tools that they lost sight of the bigger picture. Moreover, it could also be the case that the cognitive load imposed by learning the technology was so high that student teachers were left with not enough cognitive resources to attend to the process of designing appropriate technology-supported instruction.

The findings of the study suggest that preparing technology-competent teachers in teacher education programs is a challenging and difficult issue that needs to be systematically planned and carefully implemented. It seems that teacher educators need to do a better job with what Shulman (1987) calls 'pedagogical reasoning.' The term 'pedagogical reasoning' refers to the process of transforming subject matter into forms that are pedagogically powerful as well as identifying and selecting strategies for representing key ideas in the lesson (Shulman, 1987). The source of pedagogical reasoning is pedagogical content knowledge (PCK), which is a special amalgam of different components of teachers' knowledge, such as subject matter knowledge, pedagogical knowledge, knowledge of students, and understanding of the social, political, cultural, and physical environment (Shulman, 1986). Shulman (1986, 1987) described PCK as the ways content, pedagogy, and knowledge of learners are blended into an understanding of how particular topics to be taught are represented and adapted to learners' characteristics, interests, and abilities. Specifically, PCK relates to the transformation of several types of knowledge, includes an understanding of what makes the learning of specific concepts easy or difficult, and embodies the aspects of content most germane to its teachability (Shulman, 1986). Thus, PCK encompasses an understanding of students' preconceptions and learning difficulties, and includes the most useful forms of representation, the most powerful analogies, illustrations, examples, explanations, demonstrations, and other ways of representing and formulating the subject in forms that are comprehensible to learners. With the advent of computers in schools, teacher educators are responsible for adequately preparing student teachers to teach with technology. Thus, student teachers' pedagogical reasoning has to be expanded to include knowledge about how subject matter can be transformed and taught with technology tools. This expanded view of pedagogical reasoning can be described as the ways knowledge about tools and their affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics can be taught with technology in ways that signify the added value of technology.

Thus, if student teachers are not well trained to develop a clear and appropriate pedagogical rationale for incorporating computer technologies in their classrooms, then technology will never affect the teaching and learning process. Smith (1971) argued that preservice teachers would not develop this rationale without appropriate modeling from teacher educators. Nevertheless, modeling alone may not always be effective. As the results of this study showed, despite the fact that the infusion of multimedia and modeling tools was modeled repeatedly in class, student teachers in the Multimedia group failed in using the multimedia authoring tools to appropriately transform science content, support learner-centered teaching strategies, as well as integrate the tools with appropriate pedagogy in the science classroom.

Teacher educators, besides modeling, also need to explicitly explain the pedagogical reasoning that guided the design of instruction with technology, so that student teachers can experience these new visions of learning with technology and examine how the teacher's role changes, how the subject matter gets transformed, and how the learning process is enhanced. Moreover, teacher educators need to explicitly teach how the unique features of a tool can be used to transform a specific content domain in ways not possible without the tool. In other words, teacher educators have to explicitly demonstrate the added value of a tool in teaching and learning the content of a discipline. Teacher educators also need to explicitly teach their students how they can develop interactive computer activities with technology, and how these can be integrated in the classroom environment with appropriate pedagogy.

Thus, student teachers need to be given sufficient opportunities during their training to develop adequate pedagogical reasoning and to become confident and competent in infusing technology in their teaching. Therefore, as Mullen (2001) argues, teacher education programs must provide rich learning experiences for preservice teachers across the curriculum and offer them with opportunities to reflect on these experiences. Technology infusion should be implemented throughout the teacher education curriculum to allow student teachers develop a sound pedagogical rationale of how to teach with technology (Mullen, 2001).

The challenge of successfully infusing technology throughout the teacher education curriculum is multifaceted and should include a multitude of issues. Specifically, (a) it should focus on skills, since student teachers need to be able to use the technology before they design instruction with the technology. Teacher educators need to select technology tools carefully, so that the tools do not impose a heavy cognitive load on student teachers' cognitive processes during learning how to use the tools; (b) it should focus on the role of technology for supporting various instructional strategies, such as discovery learning, cooperative learning, inquiry learning, role-playing etc; (c) it should focus on the ways that technology can transform the content of a discipline to make it more accessible to learners; (d) it should focus on the ways technology changes the role of the teacher, and how the role of the teacher is enhanced with appropriate uses of technology in teaching and learning; and (e) it should focus on the importance of having teacher educators who will be committed to their course restructuring efforts, because any successful integration of technology will greatly depend on the effort and time instructors will be willing to invest in scaffolding students' learning and guiding them through the creation of appropriate technology-supported learning.

In conclusion, the results of the study seem to suggest that the integration of technology in method courses is not an easy task and requires a high commitment to gaining and extending expertise for sustained change effort. Moreover, the results show that becoming technology competent requires time and effort. Thus, student teachers will be able to effectively develop the competencies needed to teach with technology only when teacher educators systematically infuse technology throughout the teacher education curriculum.

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